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Fire Management Notes

Fire Management Notes

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Special Feature

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Aviation in Fire Management: Its Beginning in 1919 and Today

Fred A. Fuchs

Assistant director, USDA Forest Service, Fire and Aviation Management, Washington, DC

This year the USDA Forest Service is celebrating the 100th anniversary of the beginning of the National Forest System. Twenty-eight years after the first forest reserve, the Yellowstone Park Timber Land Reserve, was set aside in 1891 and 16 years after the airplane first flew in 1903 at Kitty Hawk, NC, the Forest Service began using aircraft in support of wildfire suppression. This fledgling effort used the U.S. Army Ninth Corps, commanded by Major Henry A. ''Hap'' Arnold, to fly World War I Curtiss JN–40's and de Havilland DH–4B's on daily detection patrols. In 1919, during the first year of air patrol, the dozen of these aircraft used in California from Mt. Lassen to the Mexican border discovered 550 fires. The patrol team reported their fire information to fire control officers by parachute or carrier pigeon in the field. From this promising beginning, aviation has grown to occupy a major fire suppression role.

Sixteen years after the first airplane flight at Kitty Hawk in 1903, the Forest Service began using aircraft in support of wildfire suppression.

What's New in Aircraft in the 1990's

Several new and exciting equipment developments in aviation for fire management are taking place right now. The older, piston-engined airplanes, now difficult to maintain because parts are in short supply, are being replaced with turbine-powered airplanes. In the 1990 fire season, the Forest Service extensively used four Lockheed C–130A's, two Lockheed P–3A's, and the S–2F with a Marsh turbine conversion—the ''third generation'' of turbine-powered airtankers in firefighting service.

Seven C–23A's (Sherpas), twin turboprop aircraft used to support the forces at North Atlantic Treaty Organization's bases, were acquired as U.S. Air Force excess property in 1990. The use of the Sherpas, primarily in the smokejumper program, will increase fire suppression effectiveness and reduce costs: Operating the Sherpas, which carry a large payload, is less expensive than using contract operators' airplanes. That the firefighting community now uses the Sherpas, C–130A's, and P–3A's is based in good part on the strength of communication between Forest Service Fire and Aviation Management and the military services and the support of the General Services Administration (GSA) and its Personal Property Management Division Branch headed by Staff Director Stan Duda. All military excess property is transferred to Federal agencies through the GSA.

Another exciting accomplishment in aircraft improvement is the ''remanufacture'' of the last two Forest Service DC–3's in operation. As the DC–3's—the backbone of the smokejumper program for years—aged and their piston engines became less reliable, most were replaced with de Havilland Twin Otters. The Twin Otters, which were unable to carry a 20-person fire crew or as many smokejumpers as a DC–3, did not completely meet the needs of the smokejumper program. After an extensive 10-year search for a DC–3 replacement aircraft, it was decided that modernization of the DC–3 was

Closeup view of de Havilland DH–4 on fire detection patrol (1919).

the best option. The two remanufactured aircraft with modern turboprop engines, aircraft systems, and rebuilt structures are operating this year in McCall, ID, and Missoula, MT.

The 1919 Aviation Goals and Evaluation Criteria Still Apply

As we entered the 1990's—the eighth decade of aviation in support of fire management activities—it is interesting to note that no matter how much technology has advanced, the basic policy questions in aviation for fire management that were asked in 1919 are still asked. Aviation uses found safe, efficient, and effective in 1919 continue; however, uses that failed in any one of these areas have been abandoned. For example, the 1919 air fire patrol's work was judged to be effective (550 fires reported), efficient (compared favorably with alternate methods in dollar and time costs), and safe enough, although several accidents and fatalities took place.

Of the safety, efficiency, and effectiveness goals, safety is by far the most frustrating and difficult to achieve. The standards are not only difficult to define, but also the performance in meeting those standards. As the use of aviation has increased, safety has become an increasingly important concern. Through the last 30 years, tremendous efforts have resulted in considerable reduction in accidents, injuries, and fatalities. The questions of 1919 that fire managers still ask about safety are: What is an acceptable safety level? Can we achieve an acceptable safety level at a reasonable cost and, if so, how do we do it? In some areas of fire aviation use, safety performance is high; in others, more effort is needed. Nearly 80 percent of fire support aviation accidents are caused by human error. Why do people make mistakes that cause accidents? Fire managers search for the answer, but the search is often frustrating and the answer elusive—it is a challenge that we cannot and do not give up on. On August 30, 1991, Dr. Richard Jensen, Director of the Aviation Psychology Laboratory of Ohio State University, began an independent study on Forest Service internal flight operations. Dr. Jensen's findings will set forth alternative methods and techniques to enhance aviation safety performance.

Pilot and copilot in de Havilland DH-4 prepared for fire detection flight (1920).

De Havilland DH-4 on fire detection patrol near Mt. Hood (about 1921).

The New Equipment—Does It Help?

The new aviation tools such as large helicopters and the turbine air tankers used in balance with many other firefighting tools improve firefighting effectiveness and efficiency. Their greater power reserve and flexibility also improve safety—but safety and containing its cost remain our greatest challenge. ■

Seven Sharp Sherpas—"New" Planes Soaring in Popularity

"New" airplanes added to the smokejumper fleet in 1991 promise to move more smokejumpers more efficiently. The planes, known as "Sherpas," were transferred from the U.S. Air Force under the Federal Government's excess property program.

Each twin-engine C–23A Sherpa will carry 10 to 12 smokejumpers and their equipment. Fully loaded, the aircraft's cruising range is around 450 miles (724 km) at about 207 miles per hour (333 km/h). When used as a paracargo platform, it can carry about 5,000 pounds (2,268 kg) with 3 hours of fuel.

"The planes are very well suited for the smokejumper and paracargo missions," said Nels Jensen, USDA Forest Service national aviation operations officer at Boise Interagency Fire Center (BIFC) and now a Sherpa-qualified pilot. "The performance is better than anticipated, with a good payload. It will save us a significant number of dollars in the future."

"Speed, visibility, and interior room" are the advantages of the Sherpa said Bureau of Land Management (BLM) BIFC smokejumper Ken Franz, a 17-year veteran with almost 400 jumps.

"Anything that delivers smokejumpers more quickly will help stop fires before they get big," he said. "The Sherpa's interior space makes it possible to be comfortable even with a full fire load of cargo. The visibility (of the terrain) through the windows enhances the firefight because jumpers can better orient themselves to the conditions below."

Four planes have been deployed into the field this fire season. The Forest Service has positioned its three planes at Redding, CA; Redmond, OR; and Missoula, MT. BLM has stationed its plane at the Alaska Fire Service (near Fairbanks). The remaining three will be ready by next year: two for BLM and one for the Forest Service.

Eighteen C–23A's were produced for the U.S. Air Force between 1982-84. They were used by the 10th Military Airlift Squadron stationed at Zweibrucken Air Force Base, located in what was then known as West Germany. The freighters serviced 22 U.S. Air Force bases in northern Europe.

"The planes have about 4,500 hours each," said Ed Blakeslee, Forest Service aviation maintenance specialist at BIFC. "That's equivalent to getting a mid-1980's car with 20,000 miles (32,186 km) on it."

New, the Sherpas cost about $3 million each. The estimated price of conversion to smokejumper use from the freighter configuration is about $110,000 per plane. The conversions are being handled by Western Aircraft, in Boise, under a contract administered by the Forest Service.

To prepare for smokejumping duty, windows, cabin insulation, and interior cabin linings were installed. There were some slight radio modifications, and installation of smokejumper-related equipment. The bodies were repainted to the colors of each agency.

John Hecht

A Bureau of Land Management smokejumper takes off from a C–23A Sherpa during the joint Forest Service-Bureau of Land Management demonstration May 1, 1991, near Boise, ID.

[1]This article was previously published in The Flame, 8(1) 1 and 4, Boise Interagency Fire Center, Boise, ID.

The Sherpas have a rear ramp, similar to a C–130. However, the smokejumpers will exit through the port door, as will the paracargo. (The door is removable and stored inside the plane.) The rear ramp is used only for loading cargo, but unlike the C–130, does not open in the air.

At the beginning of the season, 17 pilots were certified for the aircraft. Each has a minimum of 12 hours on the Sherpa and logged an average of 7,000 hours total flying time. Of this group, 11 will fly for the Forest Service and 6 for the BLM.

Compared with the equivalent contract smokejumper aircraft, the introduction of the Sherpa will bring an estimated savings of $160,000 annually per plane.

Technical Facts

For a better idea about the capabilities of the C–23A Sherpa, here are some of the basic technical facts about the aircraft:

- *Manufacturer.* The C–23A Sherpa, manufactured by Shorts Brothers PLC of Belfast, Northern Ireland, is a freighter version of the Shorts SD3–30 aircraft. It is named after a Himalayan people "renowned for their durability, industry, and loyalty while working in severe environmental conditions."
- *Engines.* The engine, manufactured by Pratt & Whitney, is powered by twin-propellors and is capable of developing 1,167 horsepower at 1,675 revolutions per minute.
- *Performance.* Allowable usable weight—22,400 pounds (10,161 kg); elevation—10,000 feet (3,048 m); maximum cruising speed—218 miles per hour (351 km/h); minimum cruising speed—177 miles per hour (285 km/h); cruising speed for exit of smokejumpers—115 miles per hour (185 km/h); maximum rate of climb at sea level—1,180 feet per minute (360 m/min); service ceiling (maximum altitude aircraft can operate at, one engine out—12,900 feet (3,932 m).
- *Take-off distance.* ISA—3,420 feet (1,092 m); ISA plus 15 degrees—4,250 feet (1,295 m).
- *Landing distance.* 3,650 feet (1,113 m).
- *Range.* (With maximum fuel reserves for 45-minute hold and 50-mile (81 km) diversion)—225 miles (362 km) with 7,000 pound (3,175 kg) payload; 770 miles with 5,000 pound (2,268 kg); fuel consumption (average)—130 gallons per hour (492 L/h).
- *External dimensions.* Span—74 feet, 8 inches (23 m); length—58 feet (18 m); rear loading door—height, 6 feet, 6 inches (2 m), and width, 6 feet, 6 inches (2 m).
- *Internal dimensions.* Cabin—maximum length, 29 feet, 10 inches (9.1 m); maximum width, 6 feet, 6 inches (2 m); maximum height, 6 feet, 6 inches (2 m); volume (all-cargo), 1,260 cubic feet (29 m^3); baggage compartment (nose), 45 cubic feet (1.3 m^3).
- *Weights and loadings.* Weight empty (includes crew of two)—15,370 pounds (6,972 kg); fuel (jet)—4,480 pounds (128 kg) (670 gal or 2,536 L); maximum payload—7,000 pounds (3,175 kg). ■

John Hecht, *public affairs writer, Bureau of Land Management, Boise Interagency Fire Center, Boise, ID*

Keeping Track of FEPP: Internal Control

State Foresters using loaned USDA Forest Service Federal Excess Personal Property (FEPP) for fire protection must have adequate internal controls to safeguard the equipment. Here are some actions the State Forester can take to keep better track of FEPP:

- **Separation of Duties.** The many duties connected with FEPP must be separated in such a way that no one person has enough FEPP responsibilities to obscure actions from management oversight. Segmenting duties protects the program.
- **State Reviews and Audits.** The State Forester is encouraged to conduct State reviews and audits and to participate with the USDA Forest Service in Forest Service reviews.
- **Property Identification.** All FEPP on loan should be identified as Federal property with USDA Forest Service furnished tags or labels or with a State identification system approved by the USDA Forest Service.
- **Training.** Managers and users of FEPP must be adequately trained.
- **Enforcement.** When FEPP on loan is lost, damaged, or stolen, the State Forester must find out whether State employees have been negligent in the carrying out of their duties. If negligence is determined, the State employee should be subject to the State's administrative regulations. ■

Francis R. Russ, *property management specialist, USDA Forest Service, Fire and Aviation Management, Washington, DC, and chairman of the FEPP Study Group*

Mark III Aerial Ignition: A Field Perspective

John Fort

Zone fire management officer and forester, U.S. Fish and Wildlife Service, St. Marks National Wildlife Refuge, St. Marks, FL

In the last 10 years the use of aerial ignition in prescribed burning has grown dramatically nationwide. It is now used extensively in the lower Coastal Plain of the Southeastern United States. New land managers, however, have had little exposure to the use of aerial ignition, and others are in need of more detailed information to better plan and make budget decisions.

Fire History on the Lower Coastal Plain

The lower Coastal Plain of the Southeastern United States stretches roughly from Texas to Florida along the Gulf of Mexico and up the Atlantic Coast to Virginia. Historically, this predominantly fire ecosystem burned in response to lightning strikes and Native American fire sets. Uplands, composed of species of southern yellow pine, burned frequently (2- to 10-year intervals), while the wetter sites (swamps and stream areas) of bottomland hardwood trees and midstory brush normally burned in response to prolonged drought (50- to 100-year intervals).

In this century, prescribed fire has been extensively introduced in the area. The primary method of ignition has been by hand, and types of fire included backing, head (both spot and strip), and flanking. The onset of aerial ignition has added a new dimension to prescribed fire and given the land manager another tool.

Firsthand Experience

My field positions over the last 10 years have allowed me to oversee 3,500 acres (1,416 ha) of helitorch burning and 90,000 acres (36,424 ha) of "ping-pong" (Premo Mark III aerial ignition device) burning on Federal land, all of it prescribed firing in the Coastal Plain. Ping-pong ignition has become the method of choice for most applications in the lower Coastal Plain. Helitorch is used to some extent, most often on site preparation burns and understory burns on wetter sites.

If agency goals are to be met, then aerial ignition may be viewed as a cost of doing business.

The Mark III device, mounted inside the helicopter, is a 61-pound (26.8 kg) aluminum and stainless steel frame with motor, pumps, chutes, and liquid tanks used to inject glycol into a ping-pong ball containing potassium permanganate. After the ball is injected with glycol, the machine kicks the ball out of the helicopter. Thirty to forty-five seconds later the ball ignites in an exothermic reaction.

Effective Use of Aerial Ignition

How can aerial ignition work effectively in fuels management? Answering that question requires taking a step back and asking some specific questions:

- When would aerial ignition be more desirable than hand ignition?
- What must be considered in planning for the ignition?
- How much does it cost?

The following observations, which respond to these questions, are based on my field experience and a general

A 1-mile section of Mark III spots set to back into pine flatwoods on St. Marks National Wildlife Refuge and head through marsh grass.

understanding of issues affecting prescribed burning. They are not the result of a controlled scientific study.

To Hand Burn or Ignite by Air. An oversimplification of when to use aerial ignition is almost whenever (and wherever) one would handburn. The manager is simply substituting one method of ignition for another. The goals of the land manager can be met by either hand or aerial ignition. Hand ignition is an accepted and expedient method of ignition. Aerial ignition requires more preparation, but the end results are often superior because the quantity of work can be dramatically increased and the quality of work can be better ensured. Here are four examples of superior results:

- Better coverage of an area
- Tighter control of the ignition process
- More effective smoke management
- Burning goals achieved in a higher quality manner

Constraints on Burning. Land managers have a set of prescribed burn goals to achieve—acres burned, tons of fuel reduced, certain understory species targeted—and a finite amount of resources—dollars, time, favorable weather—to accomplish these goals. Recent political and social changes have combined to limit these resources, constraining when burns may occur. Dollars are fewer to fund the same (or greater) goals. Personnel ceilings have limited the number of people on the ground to do the burning. State smoke management and air quality requirements limit the days when burning is allowed—further constraining the "weather window"—through restrictive and necessary smoke management criteria.

Advantages of Aerial burning. Aerial ignition can allow goals to be met within additional constraints. Aerial ignition allows the burnout of specified areas in a much shorter timeframe (hours instead of days) than handburning. Fewer people can cover more acres if the method of ignition is aerial. Short-lived "weather windows" can be used to full advantage. Smoke management criteria can be met by compressing a set volume of smoke into a large column and allowing for rapid dispersal. Smoke concerns become more compelling as the duration of the burn increases. Aerial ignition minimizes the duration of the burn.

Although useful, aerial ignition is not a panacea for all burns. Generally, if an area is going to be a concern with hand ignition, it will be a concern with aerial ignition. When these areas are encountered, aerial firing might allow the manager to resolve the situation effectively and meet assigned goals. For example, aerial ignition may allow the manager to take better advantage of marginal weather conditions or better treatment of marginal fuels by generating more or less heat. If an area can be easily handburned, it can also be easily lit by air, allowing the lighting of several easy areas in a much shorter period of time and thus reducing cost per acre.

Aerial Ignition Planning

How aerial ignition is used will determine whether results are satisfactory and whether goals are successfully met. Success can be insured by thorough planning and proper implementation.

Planning Is Critical. Hours of planning should precede the brief period of implementation (ignition). This means establishing the basics: The weather and fuel parameters, smoke criteria, and fireline sites. Variables unique to aerial ignition must be covered. Some of these variables are aviation safety concerns, location of the closest helicopter and fuel source, adequate landing sites, effective communication, source of a Premo Mark III machine and ping-pong balls, coordination with local aviation authorities, and use of trained people. With proper planning, ignition by air can be straightforward and as expedient as hand ignition. The actual firing mimics hand-ignition methods.

The Costs

Two of the most common planning concerns are whether dollars will be available and if satisfactory production can be realized. Table 1 may help answer these questions. The table reports field data collected from 84 aerial ignitions at 5 reporting stations for 5 years. The ignitions were by the Premo Mark III device and were on 91,377 acres (36,980 ha) of Federal lands in the lower Coastal Plain. The burns occurred during the months of October through March and reflect various Federal land management goals, although the dominant one is fuel reduction. A variety of weather and fuel conditions is represented. The predominant fire behavior model is No. 7 Southern Rough (Anderson 1982) and National Fire-Danger Rating System Model D (Deeming 1975). Various types of helicopter contracts and

Table 1—*Summary of Mark III ignition costs*

Fiscal year	Number of ignitions	Unit	Acres	Flight hours	Flight cost	Number of balls used	Cost of balls	Miscellaneous cost	Total cost
1991	8	St. Marks National Wildlife Refuge, FL	8,915	25.8	$11,480	23,250	$ 3,138	$ 644	$ 15,262
1990	17	Wakulla Ranger District, FL	20,663	40.4	13,699	45,300	6,116	1,346	21,161
1989	5	Wakulla Ranger District, FL	7,400	19.5	5,710	35,500	4,792	504	11,006
1988	9	Wakulla Ranger District, FL	9,880	22.4	4,735	30,250	4,082	1,024	9,841
1987	13	Biloxi Ranger District, MS	6,670	11.4	1,833	20,250	2,735	1,934	6,502
1987	21	Wakulla Ranger District, FL	22,485	74.9	19,900	133,000	17,955	2,775	40,630
1987	3	Conecuh Ranger District, AL	6,326	14.5	2,334	23,600	3,186	1,901	7,421
1987	8	Apalachicola Ranger District, FL	9,038	13.2	2,124	23,000	3,103	1,240	6,467
Total	84		91,377	222.1	$61,815	334,150	$45,107	$11,368	$118,290

hourly flight rates were used, and three types of helicopters were flown. Other costs such as planning, overhead, agency salaries, and agency equipment are not included.

The acres column refers to those acres actually burned. The flight cost is based on the hourly leasing rate of the aircraft. The flight hours are those helicopter hours (from the ship's hour meter) needed to ferry ignition devices to the burn site, observe the area, and light the burn. The flight cost is based on the hourly rate of the aircraft. The cost of the ping-pong balls (aerial ignition devices) is held constant at 13.5 cents each. Some items included in miscellaneous costs are for daily helicopter availability, fuel truck, and costs required by contract.

A few observations drawn from these ignitions follow:

- The average total aerial ignition cost per acre was $1.29.
- The average number of ping-pong balls dropped per acre is 3.6, at a cost of 49 cents per acre or 38 percent of the total per acre cost.
- The average number of acres lit per flight hour was 411.

Per acre costs for air ignition vary widely and are tied directly to management goals and methods used to carry out the burn. For example, a reduction in the number of balls dropped or a modification of the firing pattern can lower the cost, or a decision to use aerial firing on small areas for smoke management reasons can raise the cost. Costs must be viewed on a program level, and aerial ignition viewed as a tool to accomplish the entire burn program. The overall saving in time—and therefore money—may outweigh the additional cost of ignition. If agency goals are to be met, then aerial ignition may also be viewed as a cost of doing business.

In the Federal sector aerial ignition is well established and increasing as more managers understand the procedure and are exposed to the benefits. Most questions and issues connected to aerial ignition can be resolved if a thorough job of planning is done before executing the burn. Properly applied, aerial ignition can complement hand ignition and open an opportunity for future land management objectives to be attained in a quality, cost-effective manner. ■

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Goals of Prescribed Fire on the Coastal Plain

- Site preparation for regeneration
- Cattle range improvement
- Understory fuel reduction
- Control of certain midstory plants
- Stimulation of understory species for wildlife
- Restoration of ecosystems
- Visual enhancement
- Maintenance of marshes and wetlands

Workforce Diversity Projects: Creativity in Recruitment

Elizabeth Kalish and Brenden Tu

Graduate students in Cooperative Education Program; USDA Forest Service; Rocky Mountain Region; Air, Aviation, and Fire Management; Lakewood, CO

The Rocky Mountain Region, or Region 2, of the USDA Forest Service has a cooperative education program that has as one of its goals to increase workforce diversity in fire management by investing in the education of professional fire managers. We are two of the students currently involved in the program and would like to tell you about the program: Its advantages to the agency and to us.

Brenden Tu

I graduated from the University of California, Davis (UC Davis) in resource science with a forestry emphasis. My first experience with wildland fire was as a member of the Davis handcrew organized by the Mendocino National Forest. I worked for the Davis handcrew for three seasons, 1986–88. While in school, I was also involved with the City of Davis Volunteer Fire Department. After graduating from UC Davis, I decided to further pursue my interest in fire behavior and fire management.

In August 1990, I started my master's degree program at Colorado State University (CSU), funded by the Rocky Mountain Region Cooperative Education Program. During the summer of 1991, I was detailed to the Redfeather Ranger District of the Arapaho and Roosevelt National Forests to collect data for my master's thesis. I am looking at the economics of rural fire protection—particularly Federal grants to volunteer fire departments. The evaluation of the rural fire protection programs could aid in the distribution of Federal funds to States and volunteer fire departments.

Elizabeth Kalish

I started working in fire management in 1986 while taking time off from college to assess my career goals. After spending 2½ years at the University of Arizona studying history and working with the athletic department, both as an athlete and a trainer, I took a job with Mesa Verde National Park helitack crew. I spent two extended seasons at the park working in helitack and fire dispatch.

At the beginning of 1988, I returned to school, now at CSU, in the natural resources management program. I spent the following summer working on a resource management crew at Rocky Mountain National Park. During the fall of 1988, I decided to pursue fire management as a career and accepted a position as a cooperative education forester in the Rocky Mountain Region Cooperative Education Program. I spent the first two summers working in the prescribed fire program on the Pike National Forest. I completed my bachelor's degree in December of 1990.

In January 1991, I started work on my master's degree at CSU in forest fire sciences with my funding also coming from the cooperative education program. Through a joint effort between the USDI National Park Service and the USDA Forest Service, I was able to work at the Dinosaur National Monument, collecting data for my master's thesis. I am developing a standardized live fuel moisture sampling method for sagebrush, a method for use in prescribed fire planning. The method is designed to be cost-effective and easy for managers to use in the field.

What the Program Has Meant to Us

The opportunities this program has offered us have been outstanding. In the summer of 1990, we collected data for a prescribed natural fire plan on the South Platte Ranger District of the Pike National Forest. This is one of the first plans of this kind in the Rocky Mountain Region. During the schoolyear, we worked with the region's National Fire Management

Elizabeth Kalish and Brenden Tu with Chief F. Dale Robertson on their trip to the USDA Forest Service Washington Office.

Analysis System coordinator in the Supervisor's Office on the Arapaho and Roosevelt National Forests. We have participated in training in many areas—fire behavior, prescribed fire management, and fire suppression.

In May of 1991, we visited both the Intermountain Forest Fire Laboratory (IFFL) in Missoula, MT, and the Washington Office. Al Roberts, regional coordinator of the cooperative education program, took us to Missoula for the IFFL open house. There we were able to observe ongoing research and talk to the scientists about their work. During our 2-day visit to Washington, we attended the daily meeting of Chief and Staff where we met Chief F. Dale Robertson. At the State and Private Forestry staff meeting, we met Deputy Chief Al West. We had a chance to discuss with Forest Service Fire and Aviation Management Director L.A. (Mic) Amicarella and National Park Service Fire Management Director Elmer Hurd the agencies' different fire policies and how Federal agencies work together to manage fire despite their different land management missions. The trips to IFFL and the Washington Office gave us the opportunity to discuss our thesis topics with scientists and fire management specialists.

"The opportunities this program has offered us have been outstanding."—*Elizabeth Kalish and Brenden Tu*

The main goal of the program is to diversify the fire management workforce by actively recruiting and training professional fire managers with natural resource backgrounds. Although we would both be studying fire management and working in this field, this program has allowed us to pursue broader goals. This program has expanded our knowledge of the full range of fire management activities—research, suppression, and prescribed fire. The program has given each of us the opportunity to pursue an advanced degree at a university with one of the leading fire programs in the United States. When we graduate, the Forest Service will have two employees from diverse backgrounds with an understanding not only of fire management but of the agency. ■

A TaskForce Recommendation—Funding for Special Projects

"Designate annual funding of $580,000 per year for special projects" to recruit and retain minorities and women in the workforce, Fire and Aviation Management's workforce diversity taskforce recommended in its report, "A Model for Workforce Diversity," published in April 1990. The taskforce was established in 1987 to help Fire and Aviation Management work toward the workforce diversity goal articulated in the Forest Service vision statement, "Caring for the Land and Serving People": "We will have a workforce that better reflects the national diversity." Chief F. Dale Robertson and others have reaffirmed this message many times since. The taskforce annual funding recommendation rests firmly on the old challenge—"Put your money where your mouth is!"—and the realistic insight that to build a diverse workforce in fire management requires an investment in students and their education.

A Winning Project Proposal From the Rocky Mountain Region

Cooperative Education. In response to this opportunity to build a diverse workforce, each region submitted project proposals, "bidding" for shares of the $580,000. The Rocky Mountain Region's project—to add four cooperative education positions in the Air, Aviation, and Fire Management unit—was one of the projects selected for funding.

Program Goals. The goals of the Rocky Mountain Region Cooperative Education program are to diversify the Fire and Aviation Management workforce by proactively recruiting and training professional fire managers with a natural resource background. Students are introduced to many Forest Service programs from the district to the national level. Although their university tuition is not paid, students have worked summer seasons at the district level on the Pike and San Isabel and the Arapaho and Roosevelt National Forests in recreation, timber, and fire management. Throughout the schoolyear, part-time employment has been available at the forest supervisor's office, working with the National Fire Management Analysis System (NFMAS). The cooperative education program positions give Fire and Aviation Management the opportunity to recruit university students directly into fire management.

People Behind the Scenes

Many people have devoted time and energy to develop this quality program for the cooperative education students. Al Roberts, regional team leader for the Prescribed Fire and Fuels Management Program, spearheaded the effort to get the cooperative education program underway and coordinated the activities. Rocky Mountain Region Air, Aviation, and Fire Management director, Ray Evans, has shown exceptional commitment to the advancement of this program. The Washington Office of State and Private Forestry Fire and Aviation Management funded the program and offered strong support. The tie binding the Rocky Mountain Region's cooperative education program together with CSU starts with the enthusiasm and cooperation of Dr. Phil Omi, professor of forest fire science.

Looking to the Future

Universities, particularly those with forestry schools, are excellent sources of future professional fire managers. Recruitment and training of these students in this program gives students an opportunity to learn about the importance and the nature of programs in the agency, especially fire management. Students gain work experience and can move as productive, informed employees into the agency workforce when they graduate.

The Students

The program currently employs four students from Colorado State University (CSU). Besides Brenden Tu and Elizabeth Kalish, Aaron Ortega, an undergraduate student in forestry with an emphasis in fire management, and Michelle Lyon, master's degree student in forest fire science, are also in the program. Karen Ogle, a past cooperative education student, is currently working on the Malheur National Forest.

Aaron Ortega. Originally from Lafayette, CO, Aaron Ortega—a water-skiing, wind-surfing, and rock-climbing buff—became interested in forestry while teaching biology to sixth-grade students at an outdoor laboratory. He was particularly fascinated with the effects of fire on the natural processes in different ecosystems. The cooperative education program enabled him to pursue this interest as well as others.

The cooperative education program did something else important for Aaron—a solid introduction to many different types of field operations conducted by the Forest Service. During the past 2 years, he trained in fire prevention and suppression, timber inventory, trail building and maintenance, and recreation, and has two more working summers before completing his degree at CSU. He says, "I feel very fortunate to participate in the program and believe it has given me the support to complete my goals successfully."

Michelle Lyon. Michelle Lyon devoted little time to the outdoors while growing up in Baltimore, MD. But when she graduated from the University of New Hampshire in May of 1991 with a degree in forest science, she had not only become someone who enjoys hiking, biking, sailing, and skiing, but someone closely acquainted with the challenges of land management. Interested at first in continuing her study of forest decline, which she had begun as an undergraduate, she decided to pursue fire management after witnessing a small prescribed burn in New Hampshire. As a graduate student at CSU, Michelle is focusing on how fire has been manipulated and suppressed in the past to create the forests, fire regimes, and fire behavior we have today.

Karen Ogle. Karen fell in love with the outdoors as a child during the 2 years she spent living in an undeveloped subdivision of Anchorage, AK, where there was woods and wildlife. Later, when her family moved to Denver, she hiked on many weekends and for one summer worked at Rocky Mountain National Park in the Youth Conservation Corps (YCC). During that summer with the YCC, she decided to pursue a career in natural resource management when she was older.

In 1981, she enrolled in the forestry program at CSU and in 1985 graduated with a fire management degree. During the summer of 1985, she worked as a firefighter on the Eagle Ranger District of the White River National Forest, and at the end of the summer met with Al Roberts, team leader for the Prescribed Fire and Fuels Management Program in the Rocky Mountain Region, to discuss permanent employment. Out of this discussion the cooperative education program was born. In 1988, she received her Master of Science degree in fire ecology from CSU.

Her first job with the Forest Service was on the San Juan National Forest in southwestern Colorado. There she worked on the forest's National Fire Management Analysis System (NFMAS) runs for several months before she transferred to the Malheur National Forest in eastern Oregon as the forest fire planner and fuels specialist. In 1989, Karen was detailed to the Redmond Interagency Hotshot Crew and experienced many kinds of firefighting situations. She returned for 2 years to the Malheur National Forest supervisor's office to update NFMAS runs and is currently a fuels forester in charge of the burning program on the Prairie City Ranger District on the Malheur. She will manage the suppression program on the district in the summer of 1992. ■

CDF's Helicopter Program: What's Happening

Arthur H. Trask

Helicopter program manager, California Department of Forestry and Fire Protection, Sacramento, CA

New Helicopter Maintenance Facility

The California Department of Forestry and Fire Protection (CDF) recently opened a new helicopter maintenance facility at Yolo County Airport. Unlike the previous maintenance vendor located at Stockton, CA, maintenance at the Yolo County facility is dedicated strictly to CDF helicopters. This facility with its 10-person, fulltime workforce should improve accountability—tracking parts, completing repairs, and controlling quality—and, it is hoped, result in overall cost savings.

Help From FEPP

Shop Equipment and Replacement Parts. The CDF equipped the shop with tools and spare replacement parts. Most of the shop tooling came through the USDA Forest Service Federal Excess Personal Property (FEPP) Program. Use of FEPP has been extremely cost effective for the State, saving, for instance, approximately $250,000 in shop tools alone. The CDF ultimately intends to establish one centralized maintenance facility for both airplanes and helicopters at Mather Air Force Base. The present helicopter maintenance contract contains the flexibility to relocate to Mather whenever space becomes available.

The "Super Huey." The accompanying "before" and "after" photograph shows the EH–1H helicopter as it looked when obtained from the U.S. Army and the CDF's recently completed conversion, the Copter 202, a highly modified "H" model nicknamed "Super Huey." These Hueys are acquired by the Forest Service and then loaned to agencies such as CDF for use in wildland fire suppression. The refurbishment and conversion process is both extensive and—at a cost of $505,000 per helicopter—expensive. Helicopters play a critical role in the CDF fire suppression program, and given the cost for the commercial alternative (a Bell 212 helicopter with a purchase price of $4 million each), these refurbished, converted FEPP helicopters with an expected operational life of 20 years are truly a bargain.

The Copter 202, the second CDF "H" model to go into service, became a part of the Bieber Helitack Unit on April 2, 1991. The first "H" model, Copter 205, went into service before the 1990 fire season and has subsequently flown approximately 675 hours.

The EH–1H helicopter as obtained from the U.S. Army and Copter 202 CDF conversion.

The Copter 205, CDF's first conversion of the UH–1H.

Based on our operational experience with Copter 205, we have made minor changes to the VHF radio equipment and design of the instrument panel in the Copter 202. To ensure a completely standardized fleet—*essential to flight safety*—all future "H" models will be a clone of Copter 202. To do this, the following equipment must be installed or changed:

- High-skid gear (increases ground clearance) and rotor brake (reduces rotor coastdown time significantly)
- 205A1 tailboom with 212 tail-rotor components (commercial standard)
- New particle separator (engine air filter)
- Engine upgrade (greater horsepower output): –13BA to the –703 used in the Cobra (AH–15)
- Teledyne Avionics Power Analyzer and Recorder
- Fuel management system coupled to the navigational radio (Loran C)
- Main rotor transmission upgrade: eight planetary gears with heavy-duty input quill
- Becker Avionics self-contained VHF radio stack
- Blind altitude encoder coupled to Loran C
- Wulfsberg Flexcom FM system with control head (C1000)
- Wulfsberg 9600 VHF FM with control head (C962A)
- Wire strike kit (wirecutter)
- Cargo hook load cell (external load weighing system)
- Computer system for fire mapping
- Video and infrared system
- Pilot and copilot mirrors for under-aircraft viewing
- Foam concentrate tanks built into passenger steps (20 gal or 76 L)

Given the alternative—a Bell 212 with a purchase price of $4 million each—these refurbished, converted FEPP helicopters with an expected operational life of 20 years are truly a bargain.

- Aircraft stripping and repainting, inside and out
- Complete replacement of flexible fuel and oil lines
- Solid-state inverters
- Radar altimeter with expanded helicopter scale
- New audio control panels with rear cabin public address system
- Public address system with siren activation button on pilots' collective pitch control

The recent acquisition of "H" models was very timely since CDF's existing fleet of 10 UH–1F's are faced with a critical shortage of spare replacement parts.

While the "F" models have performed yeoman service for CDF during the past 10 years (18,000 hours), the helitack bases are anxious to receive their new "H" models because of their increased performance and reliability.

Value of Helitack Program

Perhaps the best indicator of the value of CDF's helitack program can be found in the annual review of activity and accomplishment. For example, during the 1989 fire season, which was a relatively quiet fire year for CDF, the eight UH–1F helitack units performed as follows:

- 2,817.7 total flight hours
- 885 flight hours spent dropping foam
- Over 3 million gallons (11 million L) of foam or water (dropped on average of 3,450 gal or 13,000 L per flight hour)
- 2,482 firefighters transported
- 125,857 pounds (57 kg) of equipment transported
- 100 flight hours assisting in earthquake relief

Private Sector Concern

In response to concerns from the private sector, CDF conducted an extensive cost-analysis study of the agency-operated program. This recently completed study clearly shows the benefits of the program:

- Standardized flight operations
- Increased capabilities and performance
- Vastly improved safety record
- Reduced cost
- Year-round availability
- Helicopter modified specifically for fire suppression mission
- Experienced forestry pilots

CDF attributes much of the helicopter program's success to these benefits and results. ■

Fire Behavior Training—a Look at Some Upcoming Changes

Donald W. Carlton

Fire planning specialist, USDA Forest Service, Pacific Northwest Region, Portland, OR

The Fire Behavior Committee and Its Goals

In April 1990, a group of fire behavior subject matter experts was formed to work with the National Wildfire Coordinating Group's (NWCG) Training Working Team (TWT) on fire behavior issues—especially fire behavior training. The group, or Fire Behavior Committee (committee), as it is known, together with TWT, focuses its work on the development and maintenance of national, regional, and local interagency fire behavior training curriculum and courses. The NWCG TWT and the Prescribed Fire and Fire Effects Working Team (PFFEWT) have been working on fire behavior training revisions since 1988. The committee's highest priority task is the revision of the fire behavior curriculum to satisfy users in wildfire suppression and prescribed fire management. The committee is also available to agencies needing expert advice on other problems related to fire behavior.

The committee is made up of the following members: Don Carlton, Chair, USDA Forest Service, Pacific Northwest Region, Portland, OR; Bill Clark, USDI National Park Service, Washington Office at Boise, ID; Greg Zschaechner, USDI Bureau of Land Management, Colorado State Office, Denver, CO; Paul Werth, National Weather Service, Boise Weather Service Office, Boise, ID; Mike Wallace, USDI Bureau of Indian Affairs, Washington Office at Boise, ID; Pat Andrews, Intermountain Fire Sciences Laboratory, Missoula, MT; and Dan Francis, California Department of Forestry and Fire Protection (CDF) and TWT liaison, CDF Training Academy, Ione, CA.

The Fire Behavior Committee's highest priority task is the revision of the fire behavior curriculum to satisfy users in wildfire suppression and prescribed fire management.

The Fire Behavior Curriculum—How It Developed

The current core structure of fire behavior training is a result of several courses developed independently over the past 10 to 15 years, each at a different time. These courses—S–190 Introduction to Fire Behavior, S–390 Fire Behavior, and S–590 Fire Behavior Analyst—were developed primarily in response to advances in fire behavior prediction technology or methodology. In 1976, for example, the fire behavior prediction nomograms were introduced by Frank A. Albini (1976) and used in the first Fire Behavior Officer—now S–590 Fire Behavior Analyst—course. These nomograms, together with area and perimeter models, provided the basis for the Fire Behavior Prediction System (FBPS) (Rothermel 1983).

In 1979, with the introduction of the fire behavior program on the TI–59 calculator, fire behavior calculations could be made electronically (Burgan 1979). By the mid-1980's, further equipment and programming developments resulted in FBPS outputs being processed using a handheld "computer" called the HP–71B (Susott and Burgan 1986) and using the BEHAVE System on a mainframe or personal computer (Andrews 1986, Andrews and Chase 1989). As each of these fire behavior processors came online, additional fire behavior prediction models were developed to predict fuel moisture (Rothermel 1983 and Rothermel et al. 1986), spotting distance (Albini 1979, 1981, 1983), fire containment (Albini and Chase 1980), scorch height (Van Wagner 1973), and tree mortality (Ryan and Reinhardt 1988). The most recent addition is a program in the BEHAVE System called RxWINDOW (Andrews and Bradshaw 1990). A fire behavior specialist can calculate the environmental conditions (fuel moisture, windspeed, and wind direction in various combinations) for an acceptable range of fire behavior (intensity, rate of spread, and flame length). The program is particularly useful in prescribed burning.

This technology has been transferred to the field through national training courses, which taught instructors how to transfer this technology to others (TI–59, BEHAVE, and HP–71B). Formal fire behavior prediction courses such as S–390 and S–590 also included this technology.

Expanded Curriculum

To support the TWT's efforts and give direction nationally to fire behavior training efforts, the committee has structured a four-course core curriculum:

- S–190 Introduction to Wildland Fire Behavior

- S–290 Intermediate Wildland Fire Behavior
- S–390 Introduction to Wildland Fire Behavior Calculations
- S–490 Advanced Wildland Fire Behavior Calculations

S–290 and S–490 are new to the national curriculum, while S–390 has been substantially changed. To meet specific needs, application modules will be developed. One or more core courses will be required to be completed before taking an application module. For example, S–490 is a prerequisite for S–590 Fire Behavior Analyst, a 1-week application module.

The committee has worked with the NWCG Incident Command System Working Team and the TWT to integrate into the fire behavior courses the information and activities necessary to develop the skills to perform the tasks required in fire suppression positions. Currently, that integration is taking place in the course revision.

Broad Outline of Course Changes and Why Changes Were Made

S–190 will still be a required course for the basic firefighter. The course will be updated but with little change in course objectives. Much discussion has focused on which suppression and prescribed fire positions require the knowledge and skill to calculate fire behavior variables such as spread rate and flame length as currently taught in the 1981 version of S–390. For fire suppression, the committee recommended that the single resource boss does not need to do fire behavior calculations; on the other hand, the committee concluded that strike team and task force leaders and Incident Commanders Type III do need the knowledge and skill to do calculations. This decision required splitting the S–390 course, 1981 version, into two courses, separating the qualitative and quantitative parts into S–290 and S–390, respectively. The courses will be updated to include the latest technology and information.

The need for additional fire behavior predictive capability to support suppression activities on large fires as well as the planning and execution of both management-ignited and prescribed-natural fire provided the impetus for the S–490 course.

As the curriculum was expanded, the courses were carefully revised. Care was taken to introduce and develop concepts, the models based on these concepts, and the processors (tables and computers) needed to make the calculations so that a logical and orderly curriculum was developed. For instance, in S–190 and S–290, fire behavior concepts are introduced and carefully explained. In S–390, the concepts reviewed and fire behavior prediction models are introduced. In S–490, the student learns to use the processors and make the most complex fire behavior calculations. The courses build on each other, making use of what has been introduced, spiraling to the learning of more advanced concepts taught in upper-level courses.

The Course Content and Development Schedule

S–190 Introduction to Fire Behavior. The committee will review S–190 to recommend revisions, if needed, to the course in fiscal year 1992. The film, "Fire Weather," an integral part of S–190, is being revised. Testing will occur in fiscal year 1993.

S–290 Intermediate Wildland Fire Behavior and S–390 Introduction to Wildland Fire Behavior Calculations. The major changes from the existing S–390, 1981 version, to the new courses are:

- Developed S–290 as an instruetor-taught course with a strong prework component. The course is proposed as a requirement for the single resource boss. Classroom time is estimated at 24 hours.
- In S–290, included a unit where the student learns how to analyze the influences of combined topographic, weather, and fuel factors on fire behavior. A job aid (step-by-step explanation of task) will be developed which the student can easily carry to the fireline.
- In S–290, developed an in-depth unit on the concepts of fire behavior in the third dimension (extreme or severe fire behavior). This unit includes many of the concepts taught in the existing S–490 lesson on this subject.
- Developed S–390 as an instructor-taught course with a strong prework component. Classroom time is estimated at 16 hours, and it is proposed that this course be required for strike team and task force leaders as well as the Incident Commander Type III.
- In S–390, replaced the calculation of fire behavior values using tables with fire behavior nomograms.
- Wrote detailed lesson plans and produced effective audio-visual

material for all fire behavior courses.

- Updated and standardized terminology throughout the fire behavior curriculum.

The course outlines are as follows:

S–290 Intermediate Wildland Fire Behavior

Unit 0	Introduction
Unit 1	The Fire Environment
Unit 2	Basic Weather Processes
Unit 3	Temperature/Humidity Relationships
Unit 4	Atmospheric Stability and Clouds
Unit 5	General and Local Winds
Unit 6	Topographic Influences on Fire Behavior
Unit 7	Fuels
Unit 8	Fuel Moisture
Unit 9	Keeping Current with the Weather
Unit 10	Wildland Fire Behavior in the Third Dimension
Unit 11	Combining Influences Affect Basic Fire Behavior
Unit 12	Regional Lessons (Optional)

S–390 Introduction to Wildland Fire Behavior Calculations

Unit 0	Introduction
Unit 1	Fire Behavior Inputs
Unit 2	Fire Behavior Calculations
Unit 3	Fire Behavior Applications

The committee structured a development plan for S–290 and S–390, allowing for the completion of draft courses for both S–290 and S–390 in fiscal year 1991, four test courses in fiscal year 1992, and course distribution in fiscal year 1993. The first test course for S–290 and S–390 was held in Boise, ID, January 6–10, 1992. This course also served to train instructors for the other three test courses. The other test courses were held in California January 27–31, the Southeast March 2–6, and the Southwest March 9–13. Regional agency representatives attending courses were invited to critique them. Final revision, which will include the evaluation of trainees, instructors, and agencies, will occur following the test courses with course revision completed by October 1, 1992.

S–490 Advanced Wildland Fire Behavior Calculations. S–490, with its adjustments to regional conditions has been tested and will be available in mid-1992. Test course development, geared to the regions, is on schedule. The course outline is as follows:

S–490 Advanced Wildland Fire Behavior Calculations

Unit 0 Introduction

Unit 1 Wildland Fire Behavior Inputs
- A. Use of Models
- B. Fuel Moisture
- C. Fuels
- D. Atmospheric Stability
- E. Wind
- F. Securing, Adapting, and Verification of Weather Forecasts

Unit 2 Wildland Fire Growth Projections
- A. Basic Wildland Fire Growth from a Point Source
- B. Spotting and Ignition
- C. Wildland Fire Behavior on Slopes
- D. Large Wildland Fire Prediction and Behavior
- E. Calibration
- F. Fire Whirls
- G. Wildland Fire Behavior in the Third Dimension

Unit 3 Optional Regional Lessons
- A. Calculation Proficiency Assessment
- B. Prework Review—HP–71B
- C. Prework Review—Slope Determination
- D. Prework Review—Mid-flame Wind
- E. Prework Review—Nomograms
- F. Prework Review—Fine Fuel Moisture Determination
- G. Prework Review—BEHAVE
- H. Burn Fuelbed
- I. MOISTURE Module
- J. CONTAIN Module

Other Training Materials and Courses, Technology Transfer, and Equipment

Review of Materials in the Publications Management System. The committee is reviewing the materials currently in the Publications Management System (PMS) at Boise Interagency Fire Center that support fire behavior and fuels management training. The committee is providing the leadership to research the publications needed for training or operational purposes. The Mack Lake Fire (Simard 1983) and relative humidity tables are now available.

Commonly used items in fire behavior training such as the fire behavior worksheets in standard packs by worksheet type, fire behavior nomograms, BEHAVE program computer disks, and a fire behavior field reference to support S–490 will be stocked by PMS in the future. Users should consult the NWCG National Fire Equipment System Catalog, Part 2: Publications for instructions on how to order and availability.

Newsletter. The committee continues to explore ways to improve communication within the fire behavior community. An informational fire management newsletter, under the leadership of Robert Mutch, Forest Service technology transfer specialist at Intermountain Fire Sciences Laboratory Missoula, MT, will be published periodically. The newsletter, titled "Interactions," will share new information and update fire behavior and fire management developments.

Prescribed Fire Training Support. The committee is working closely with the NWCG Prescribed Fire and Fire Effects Working Team to formulate draft national prescribed fire qualifications and training standards. Fire behavior knowledge and skills will be identified for prescribed fire positions allowing for the integration of these in the core fire behavior courses. In addition, some knowledge and skills will be taught through the development of prescribed fire courses. One of these courses is currently under development and will be taught for the first time at the National Advanced Resource Technology Center in November 1992. This course will cover the use and application of the Fire Behavior Prediction System and other technology in the planning and execution of management-ignited and prescribed-natural fire. It will include current state-of-the-art methodologies for both short- and long-term fire behavior projections.

Alternatives to the HP–71B for Field Use. The committee is exploring the use of IBM-compatible laptop and palmtop personal computers to run the programs in the BEHAVE system. A literature search is occurring as well as field testing of a palmtop personal computer with printer and modem that runs only on alkaline batteries. The results will be compiled following the 1991 fire season.

Information—Contact Your Agency Representative

Through the Fire Behavior Committee's efforts, many benefits have already been realized—particularly in developing fire behavior curriculum and courses more effective in training fire managers and officers in carrying out the fire suppression and prescribed fire program. The proper use and application of fire behavior prediction technology is critical to the execution of both programs. If you need more information on the activities of the committee or wish to assist in its efforts, please contact your agency representative. Their telephone numbers are: Bill Clark, NPS—FTS 554–9414 or 208–334–9414; Greg Zschaechner, BLM—FTS 554–3808 or 303–239–3808; Paul Werth, NWS—FTS 554–9862 or 208–334–9862; Mike Wallace, BIA—FTS 554–2575 or 208–389–2575; Pat Andrews, Intermountain Fire Sciences Laboratory—FTS 584–4827 or 406–329–4827; Dan Francis, CDF and TWT liaison, CDF Training Academy—916–322–7912; and Don Carlton, Forest Service—FTS 423–2931 or 503–326–4931. ■

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Summer Conference: Forest Fire Lookout Association

On August 8–9, 1992, the Forest Fire Lookout Association holds its summer conference at Weeks State Park, Lancaster, NH. At the conference Keith Argow, president of American Resources Group, a nonprofit organization for nonindustrial private woodland owners that publishes *National Woodlands Magazine*, will present New Hampshire Division of Forests and Lands with a certificate placing Mt. Prospect Firetower on the National Historic Lookout Register. The Mt. Prospect tower was built in 1912 by John Weeks—of Weeks Act fame. The register, sponsored by the American Resources Group, currently lists 43 towers nationwide.

On the evening of August 8, Karl Roenke, forest archaeologist on the White Mountain National Forest, will lecture on the history of New Hampshire firetowers. Along with field trips and a publications exhibit, the conference will display 50 years of fire prevention and Smokey Bear posters.

For more information, contact J. Chris Haartz, P.O. Box 162, Campton, NH 03223; Iris W. Baird, 11 Richardson Street, Lancaster, NH 03584; Dave Govatski, Route 115, Jefferson, NH 03583, FTS 661-2626 or 603-869-2626; or Karl Roenke, White Mountain National Forest, P.O. Box 638, Laconia, NH 03247, FTS 834-3773 or 603-528-8773. ■

This primary trainer for the U.S. Navy, the Navy N3N or "Yellow Peril," was first manufactured in 1937. Modified for borate bombing, it was the first airtanker on contract with the Forest Service. Operated by Jensen Flying Service of Sacramento, CA, the aircraft was stored after the airtanker contract terminated. Unrestored, it is displayed in original colors and condition.

Tanker 21 is a Grumman AF-2S or "Guardian," a torpedo bomber modified for retardant bombing, operated by the Aero Union Corp. from 1950–57 on Forest Service and California Department of Forestry contracts.

Tanker 63 is the only Fairchild C-123 that flew as an airtanker. It was on contract at Santa Barbra, CA, from 1984 through 1988 and operated by TBM, Inc.

Retired Firefighting Aircraft Go On Display

Six retired firefighting aircraft are now on display in Pima Air Museum in Tucson, AZ. In April 1990, Pima Air Museum and the USDA Forest Service signed an agreement to display historic firefighting aircraft on loan from the Forest Service. The Pima Air Museum, a nonprofit, educational museum started in 1976, is the third largest aviation museum in the United States with 228 aircraft on display.

Through extensive coordination between John Roberts, fire management officer, on the Coronado National Forest and Ned Robinson, director of the Pima Air Museum, plans are moving ahead to add more aircraft such as the Fairchild C–119 and Lockheed P2V and to set aside a separate firefighting aircraft display area at the museum. Photographs of five of the six aircraft now on display in the museum are shown in this photo story. ■

Fred A. Fuchs, *assistant director, USDA Forest Service, Fire and Aviation Management, Washington, DC*

The Stearman NS Kaydet, modified for borate bombing, was used from 1934 into the 1940's as a training aircraft for basic training in the U.S. military. The first airtanker fleet, five Stearmans from Willows, CA, was organized for the Forest Service by Joseph Ely of the Mendocino National Forest and Willows Flying Service and used through equipment rental agreements with Willows.

The Cessna 310 was the first twin-engine leadplane widely used by the Forest Service to lead and direct airtankers on retardant drops in 1968–69.

A Fire Protection Analysis for the Beaver Creek Watershed: A Technical Fire Management Final Project

Thomas A. Wordell

Union hotshot superintendent, USDA Forest Service, Wallowa-Whitman National Forest, La Grande Ranger District, La Grande, OR

The Beaver Creek Watershed fire protection analysis was undertaken to evaluate the current La Grande Ranger District preplanned suppression response strategy in the watershed. The analysis also served to satisfy the final requirement—a case study and written report—of Technical Fire Management (TFM), a series of courses offered by Washington Institute, Inc., in conjunction with Colorado State University, to individuals with a background in fire management in public agencies who wish to improve their technical proficiency in fire ecology, fire behavior, fuels management, data analysis, and economics.

Beaver Creek Watershed

The Beaver Creek Watershed consists of approximately 15,000 acres (6,071 ha). At the time of analysis, Beaver Creek Watershed provided 65 percent of the municipal water supply for the City of La Grande, OR. The La Grande Ranger District of the Wallowa-Whitman National Forest, which administers the area, is responsible for maintaining water quality while managing other resources in the watershed. Most of the area is roadless and inaccessible by vehicles in elevations ranging from 4,500 to 6,500 feet (1,372 to 1,981 m). The plant communities in the watershed range from mixed-conifer to sub-alpine fir.

Since the mid-1970's, tree mortality caused by insect infestations and sustained drought conditions in eastern Oregon has substantially increased the natural fuel loadings within the boundaries of the watershed. When compared with occurrence in the past 20 years, fire occurrence has more than doubled in the watershed during the last 5 years.

This change in fire occurrence and buildup of natural fuels pressed fire managers to evaluate the current preplanned suppression response strategy for the Beaver Creek Watershed to find out whether protection was adequate. Current fuel profiles, fire occurrence, weather, economics, and fire effects were examined. These objectives were accomplished by the following:

- Developing a range of preplanned suppression response alternatives for the Beaver Creek Watershed using IASELECT (an initial attack computer analyzation model developed by Marc Wiitala, Pacific Northwest Region).
- Modeling the alternatives with fuels, weather, and fire occurrence data to evaluate their economical outcomes and effectiveness.
- Determining the risk of exceeding the maximum tolerable fire event that could adversely affect water quality or other resource values within the watershed for each alternative.

How Allowable Impacts Were Determined

Information from the Land and Resource Management Plan for the Wallowa-Whitman National Forest and specific input from resource specialists was used to determine allowable impacts. An interdisciplinary team (ID team), consisting of a wildlife biologist, fisheries biologist, silviculturalist, hydrologist, and fuels or fire specialist, was formed. They developed maximum impact "thresholds" or limits against which the effects of the alternatives could be compared, by reviewing forest plan guidelines, discussing wildlife concerns (cover, edges, and effects on diversity), determining suppression capabilities, and using a computer sediment yield model to estimate allowable fire size (by intensity level) that would not cause detrimental effects. Fire effects were assumed to be acceptable if fires were contained below the threshold size and unacceptable if they exceeded the threshold size.

The Alternatives

Three alternatives were quantifiably compared and evaluated in this analysis. They are briefly described below:

Alternative 1 (No Action). This alternative called for no change to the 1990 dispatch response strategy used by the La Grande Fire Zone for the Beaver Creek Watershed. It assumed all resources listed in the preplanned dispatch cards would be sent to each fire as specified by response level.

Alternative 2. This alternative used IASELECT to select the resources responding to each fire situation that resulted in the least overall cost (suppression, mop-up, and resource loss). Mitigation measures were used to reduce environmental effects by dozers and aerial retardant application.

Alternative 3. Alternative 3 modified the suppression strategy for all preplanned response levels except extreme level (where sufficient resources appeared to be currently in

place). Trial runs were made, using various suppression resources, in order to develop a reasonable alternative that balanced risk, expected burned acres, and expected annual cost-plus-loss.

Fire managers using IASELECT with procedures similar to those used in the Beaver Creek Watershed analysis could gain valuable insight useful in improving the preplanning of initial suppression responses and mitigating the costs of undesirable fire events.

Methods Used in Evaluating Alternatives

Information on fire occurrence, fuels, weather, fire behavior estimates, risk assessment, and expected burned acres and economic costs were assembled and used to evaluate the alternatives.

Fire Occurrence. Fire history records for the last 20 years (from 1970–90) on the La Grande District were examined to determine probable fire occurrence rates for the study area. During this period, according to the records, 0.11 fires occurred each year per 1,000 acres (405 ha). This is the figure used in this analysis of alternatives.

Fuels. A fuels inventory using the planar-transect method (Brown 1974) was conducted in the fall of 1989 to obtain current information on the fuel profiles in the watershed. Information from 195 data plots taken in 3 random planar transects was gathered and statistically analyzed using REFLEX, a computer database manager. The data indicated 92.3 percent of the plots were quite consistent with the standardized Northern Forest Fire Laboratory (NFFL) fuel models 8 and 10 (Anderson 1982; Andrews 1986). After the fuels inventory was completed, information was gathered from the 453 stands in the watershed to obtain a weighted representation of the fuel models by area. It was determined that 44.3 percent of the area could be represented by NFFL fuel model 8 and 55.7 percent by NFFL fuel model 10.

Weather. Weather data for only the months of June 1 through October 30 were collected from a representative remote automated weather station (RAWS). Fifteen years of weather data (1975–89) was collected from Fort Collins Computer Center and downloaded into PCFIRDAT, a personal computer program developed by the California Department of Forestry (CDF). PCFIRDAT was used to produce a cumulative frequency graph of energy release component (ERC) percentiles. On Wallowa-Whitman National Forest, these percentiles are used to determine action class levels. The fuel moisture data were then grouped into four ERC ranges, which correlated to the different preplanned dispatch response levels (fig. 1). Database manager, REFLEX, was

Estimated annual fire occurrence per 15,000 acres (6,071 ha)	Fuel model	Predispatch response level	Windspeed range		Rate of occurrence
1.55	P(Fuel model 10) 0.557	P(Extreme) 0.09	P(High wind)	= 0.13	0.0101
			P(Moderate wind)	= 0.72	0.0559
			P(Low wind)	= 0.15	0.0117
		P(High) 0.29	P(High wind)	= 0.13	0.0325
			P(Moderate wind)	= 0.72	0.1803
			P(Low wind)	= 0.15	0.0376
		P(Moderate) 0.21	P(High wind)	= 0.13	0.0236
			P(Moderate wind)	= 0.72	0.1305
			P(Low wind)	= 0.15	0.0272
		P(Low) 0.41	P(High wind)	= 0.13	0.0460
			P(Moderate wind)	= 0.72	0.2549
			P(Low wind)	= 0.15	0.0531
	P(Fuel model 8) 0.443	P(Extreme) 0.09	P(High wind)	= 0.13	0.0080
			P(Moderate wind)	= 0.72	0.0445
			P(Low wind)	= 0.15	0.0093
		P(High) 0.29	P(High wind)	= 0.13	0.0259
			P(Moderate wind)	= 0.72	0.1434
			P(Low wind)	= 0.15	0.0299
		P(Moderate) 0.21	P(High wind)	= 0.13	0.0187
			P(Moderate wind)	= 0.72	0.1038
			P(Low wind)	= 0.15	0.0216
		P(Low) 0.41	P(High wind)	= 0.13	0.0366
			P(Moderate wind)	= 0.72	0.2027
			P(Low wind)	= 0.15	0.0422

Figure 1—*Graph of predispatch response levels and action classes determined by cumulative frequency distribution of energy release components from 1970–90. Taken from PCFIRDAT.*

used to obtain average fuel moisture values by size class for each range. Associated probabilities were derived by dividing the number of days in each ERC range by the total number of days in the database. These average fuel moisture values were subsequently used in BEHAVE runs to estimate fire behavior (table 1). The probability of occurrence for each ERC range is as follows: 0–39 = 0.41; 40–49 = 0.21; 50–66 = 0.29; and 67–100 = 0.09.

Three windspeed ranges were established from historical weather data to determine average 20-foot (6.1–m) windspeeds, average midflame windspeeds and associated probabilities for each range. These values were also used as inputs to the BEHAVE runs for estimating fire behavior. (Statistical confidence intervals were determined for the average fuel moisture and windspeed values obtained. Because of the large sample size, I was 95 percent certain that the calculated average values were plus or minus 0.2 of the true average values.)

The probabilities and rates of occurrence on the branches of the decision tree shown in figure 2 summarize the environmental conditions this project used to derive the estimated annual burned acres and costs plus net value change needed to evaluate the protection alternatives.

Fire Behavior. Estimates of fire behavior for each of the possible combinations of windspeed and fuel moisture for each fuel model shown in figure 1 were derived from multiple modeling runs using the PC version 3.3 of BEHAVE. Information on area and perimeter growth over time along with fireline intensity and flame length were then entered into a suppression model for analysis and the development of alternatives.

Modeling Suppression Outcomes. IASELECT was used to model suppression outcomes against the fire behavior associated with each branch of the decision tree (fig. 2) for each alternative. IASELECT is a computer-based analysis tool designed to evaluate a wide range of economic considerations in the use of fire suppression resources for initial attack decisions (Wiitala 1989). The program permits the user to mix and match predicted fire behavior estimates with available suppression resources in order to arrive at containment times and estimated costs. It also allows the user to "optimize" available resources to arrive at the least cost-plus-loss combinations for various containment times or fire sizes. For additional information on IASELECT, contact Marc R. Wiitala of the Pacific Northwest Region.

The first step in modeling suppression outcomes with IASELECT was to create from the BEHAVE-run information fireline-containment time scenarios. These were input to a spreadsheet template in IASELECT. Twenty-four scenarios were created using the fire area and perimeter growth outputs from BEHAVE for the various fuel moistures and windspeeds previously discussed. Fire size and perimeter growth were entered in one-half hour intervals.

The next step in setting up IASELECT was determining a master suppression resource list using the preplanned dispatch cards and normal available resources able to respond to an ignition in the watershed. Response times were calculated and entered for each resource listed. These included getaway, driving, flight, and average walk-in times. The master list could then be manipulated to allow only certain resources to respond for each of the alternatives developed. All IASELECT runs were made under the assumption there was a single ignition, and all

Table 1—*Average fuel moistures by size class for preplanned response levels*

Fuel moisture level	ERC range (NFDRS fuel model G) and preplanned response level[1]			
	0-39 Low	40-49 Medium	50-66 High	67-10 Extreme
Average 1-hour fuel moisture	12.1	6.8	5.3	4.1
Average 10-hour fuel moisture	18.5	10.8	9.1	7.6
Average 100-hour fuel moisture	15.2	10.6	8.0	6.0
Live woody fuel moisture	133.9	107.7	88.0	66.5
Probability of occurrence for each ERC range	0.41	0.21	0.29	0.09

[1]ERC = energy release component; NFDRS = National Fire-Danger Rating System

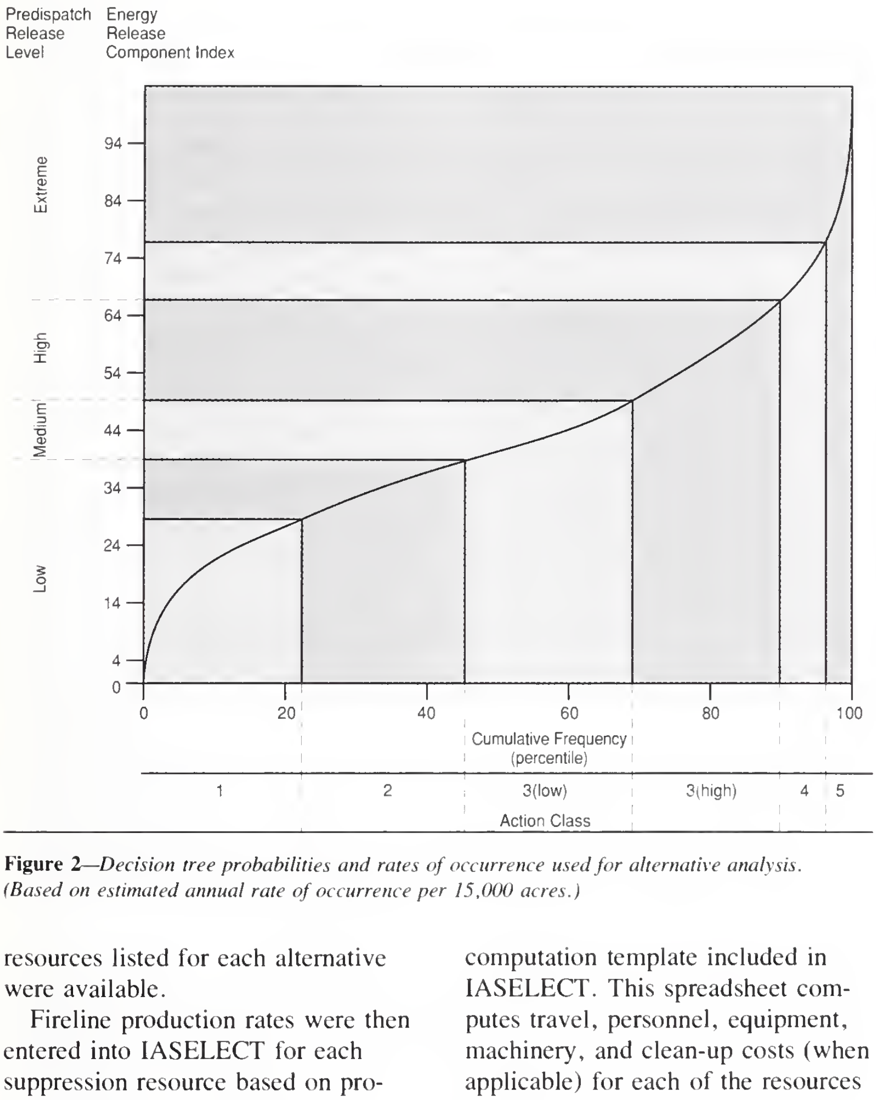

Figure 2—*Decision tree probabilities and rates of occurrence used for alternative analysis. (Based on estimated annual rate of occurrence per 15,000 acres.)*

resources listed for each alternative were available.

Fireline production rates were then entered into IASELECT for each suppression resource based on production tables in the Fireline Handbook NWCG Handbook 3 (1989), Airtanker Performance Guide (1979), and input from district suppression specialists for each fuel model. All production rates were entered in chains per hour.

Hourly and fixed suppression costs were then calculated for each of the suppression resources using a cost computation template included in IASELECT. This spreadsheet computes travel, personnel, equipment, machinery, and clean-up costs (when applicable) for each of the resources depending on dispatch response times, distance to fire, and so on.

The final requirement for setting up IASELECT was to arrive at a comprehensive estimate of total cost-plus-net resource loss for each fire event. IASELECT requires per-acre mop-up costs and composite net change for resource values. Average mop-up costs per acre were derived from a three-district cost analysis completed for the years 1986–90. Data on net resource value loss were drawn from "composite acre" net value change (NVC) used in the Wallowa-Whitman National Forest fire planning process. The composite-acre NVC is the total of all the calculated or estimated values per resource. The values used were calculated by the forest fuels specialist for the 1991 NFMAS runs on the Wallowa-Whitman National Forest.

Determination of expected burned acres and economic costs. The economic consequences of each fire event for each alternative were modeled using IASELECT. For each run, a graph was generated to show the final fire size, containment time, and associated costs. A list of initial attack resources required to meet or exceed the amount of fireline needed for each containment time was also produced.

Evaluating the Alternatives

The alternatives were evaluated based on the risk of exceeding the acceptable "threshold" acreage size as determined by the district resource specialists (see section above, "How To Find Allowable Impacts"), expected burned acres, and economic consequences from differences in suppression responses.

Risk of Undesirable Outcomes. For this project the probability (risk) of one or more fires having unacceptable fire effects was determined over time using Poisson's Distribution. Poisson's Distribution states:

$$P(k) = \frac{e^{(-ct)}\,(ct)^k}{k!}$$

Where: c = Expected rate of fires per 15,000 acres (6,071 ha) (calculated from runs resulting in a final fire size exceeding the predetermined threshold size for each alternative)

t = Time in years

k = Number of fires

e = The base of the natural system of logarithms having a numerical value of approximately 2.718...

To find the probability of one or more fire events exceeding the predetermined acceptable limits, the probability of no unacceptable fires (P(0)) was calculated and then subtracted from 1. This was done to ascertain the level of risk district managers could expect under each alternative assuming weather and fuel loadings remained constant over time.

Risk was determined annually and then over a 10- to 15-year period, which correlated to the approximate time that would be required to carry out a remedial fuels management program (see table 2).

Table 2 shows that Alternative 1 incurred approximately twice the risk over time of experiencing one or more fires exceeding the threshold fire size as Alternative 2 or 3.

Expected Burned Acres and Economic Cost of Alternatives. The economic consequences and expected burned acres were determined by multiplying the modeled fire size or cost-plus-loss by the expected rate of occurrence for each branch on the decision tree for each alternative. The expected annual results for each fire event were then added to obtain the expected annual totals for size and cost-plus-loss for each alternative as shown in Table 3.

Alternative 2 had the least expected annual cost-plus-loss and burned acres, but was based on selections made exclusively by IASELECT from a list of all resources available for initial attack in the La Grande area. Alternative 3, which increased initial attack forces on the preplanned dispatch cards from prevailing levels, indicated that overall cost-plus-loss and burned acres would decrease from the current situation shown with Alternative 1.

Conclusion—a More Aggressive Strategy

Within the limitations of this analysis—evaluating the 1990 presuppression response strategy for the Beaver Creek Watershed—it appeared the district could benefit from a more aggressive suppression strategy.

Based on 2 p.m. weather observations, fire growth exceeded initial attack capabilities 34.5 percent of the time under the 1990 dispatch strategy (Alternative 1). Many of those fires were contained with secondary suppression resources, but cost and risk could both be substantially reduced by a more aggressive response of initial attack forces as shown by Alternatives 2 and 3.

The results of Alternative 2 were based completely on optimized runs from IASELECT. Many of the runs required suppression forces that were unrealistic. Consequently, Alternative 2 did not offer a viable option to the district.

Alternative 3, through the reinforcement of additional resources, cut expected annual costs by $2,643, reduced the expected annual burned acres by 6.05 acres (2.4 ha), and most importantly decreased the risk of exceeding an acceptable fire size in the watershed by 33.7 percent over a 10-year period from Alternative 1.

Table 2—*Risk of unacceptable fire events in specified time periods*

Alternative	Expected unacceptable annual rate	Annual risk of unacceptable fire event	10-year risk of unacceptable fire event	15-year risk of unacceptable fire event
No. 1	0.1122	0.1061	0.674	0.814
No. 2	0.0426	0.0417	0.347	0.472
No. 3	0.0426	0.0417	0.347	0.472

Table 3—*Annual expected burned acres and cost-plus-loss by alternative*

Alternative	Expected annual burned acreage	Expected annual cost-plus-loss (dollars)
No. 1	16.75	$11,383
No. 2	3.50	$ 4,400
No. 3	10.70	$ 8,740

Due to the sensitivity of the watershed, I recommended increasing preplanned suppression resources as suggested in Alternative 3 until a fuels management plan could be implemented. This recommendation was presented to the La Grande fire management officer and was implemented during the 1991 preplanned dispatch review with the Oregon State Department of Forestry. Other changes were also made to strengthen the suppression response for the dispatch blocks adjacent to the watershed.

Based on this experience, fire managers using IASELECT with procedures similar to those outlined in this report could gain valuable insight that they could use to improve the preplanning of initial suppression responses and help mitigate the costs of undesirable fire events. ■

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Technical Fire Management Training

Technical Fire Management (TFM) is fire training at a high academic level. The objective of TFM is to improve the technical proficiency of fire management specialists and to teach the basic concepts in economics and statistics.

Each of the seven modules is 2 weeks long except for the first and last, which are 1 week each. The first is an optional brush-up course in basic mathematics and the use of personal computers. During the final module, each TFM'er is given the opportunity to explain a home-based project to a panel of experts, the oral presentation being a summary of the longer and more intensive written report that is required to graduate from the course.

TFM is geared to fire specialists, particularly those at General Schedule levels, 7 through 11. In particular, it attracts those agency employees who seek technical proficiency and professional development beyond what is available in agency training. The aim is to strengthen the technical and analytical skills of specialists and to give them an opportunity to solve problems likely to arise in their work.

How the Training Started and Its Current Goals

The Pacific Northwest Region (Region 6) of the USDA Forest Service saw a need for TFM training in the late 1970's as a way to improve the fire planning and management skills of its fire-related personnel. In cooperation with the University of Washington in Seattle, a course of instruction was created. After the initial 18-month series of courses, another series was held 2 years later. From 1986 to the present, TFM modules have been conducted every year, with a new series starting when the preceding series has been completed.

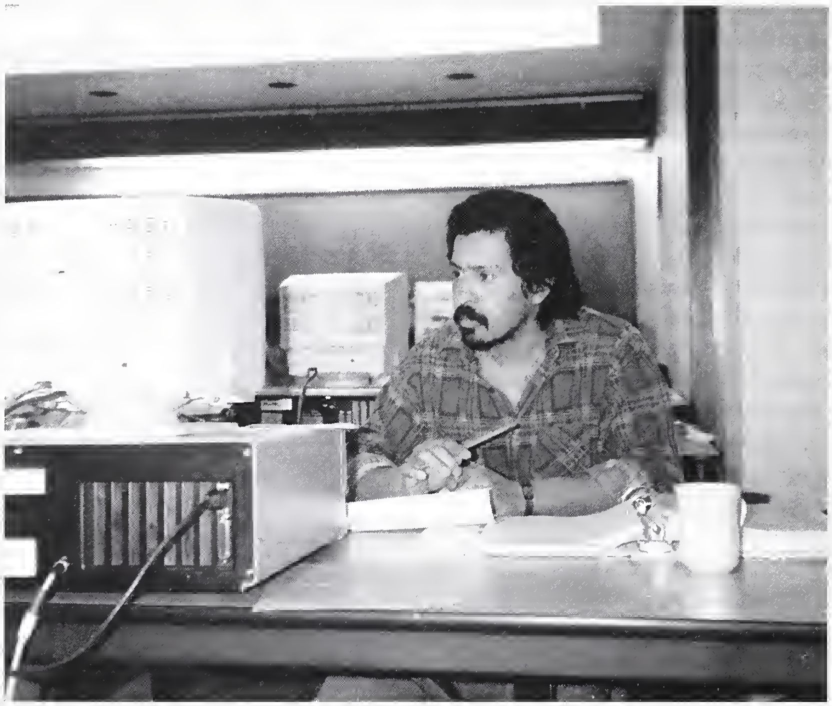
Washington Institute took on the administration of the training in 1985 after the University of Washington chose to drop it. A working relationship was forged with Colorado State University (CSU) so that college credit could be earned from the work if the student wished. Under the current arrangement, TFM graduates not only have the option of obtaining college credit, they may also qualify for the master's degree program in fire

Dr. Douglas Rideout, Associate Professor of Forest Economics, Colorado State University, teaching in Module II, Economics.

management at CSU under the direction of Dr. Philip N. Omi.

It is a continuing goal of Washington Institute to keep TFM up-to-date, not only in technological but in policy and managerial directions as well. During the first series of TFM modules, a handheld calculator was state-of-the-art. Today, the personal computer with sophisticated software is considered a basic training tool. Instructors come from academic institutions, government agencies, and private consulting firms and are evaluated regularly for their expertise and methods of teaching.

Originally, students came from the Pacific Northwest Region of the Forest Service only. The participants now come from several government agencies, Federal and State, and from many regions. Graduates of TFM can be found in nearly all western regions and a few more distant areas.



Gabe Jasso at the computer in the TFM classroom at Battelle Conference Center, Seattle, WA. Jasso is a TFM graduate and now works as hotshot supervisor on Entiat District, Wenatchee National Forest, Pacific Northwest Region.

The Curriculum

The TFM curricuulum has been developed so that each new module can build and add to what the student has learned from the previous modules. The modules and schedule are as follows:

Math and Computer Refresher (optional). To begin, the TFM participants may take this 1-week class to review mathematics and computer skills. Basic concepts are presented and some direction is given on future use of these skills in the ensuing modules.

Module I: Numerical Analysis. Following the refresher class, the first 2-week session leads the student through quantitative decisionmaking techniques that can be applied to analysis of fire and fuels management data. These techniques include applications in probability distribution, statistical testing, decision theory, and sampling methods.

Module II: Economics for Fire Managers. Approximately 2 months after Module I, participants study basic economic concepts and their application to fire suppression and fuels planning. Students learn how to conduct financial analyses and how the National Fire Management Analysis System (NFMAS) and Fuels Appraisal Process (FAP) are developed and applied.

Module III: Fuels and Prescribed Fire Management. Students investigate the components of the Fire Behavior Prediction System, including how it is constructed and how the outputs are interpreted and applied. They also learn fire hazard, fire risk, and fire danger concepts and the appropriate situations for their use, including fuel treatment plans.

Module IV: Fire Effects and the Ecology of Fire. In this module, students learn to identify the direct causes and effects of fire. Evaluation of a site to determine the historical role of fire and the effects of future management with or without the application of fire is also undertaken. Module IV is held in late spring and includes a field trip with a case study assignment.

Module V: Fire and Land Management. Module V, the last 2-week module, explores legislative, political, sociological, and legal considerations of fire management. There is emphasis on decisionmaking through the use of the rational planning process as well as investigation of methods for monitoring and evaluation. Each student develops an individual outline

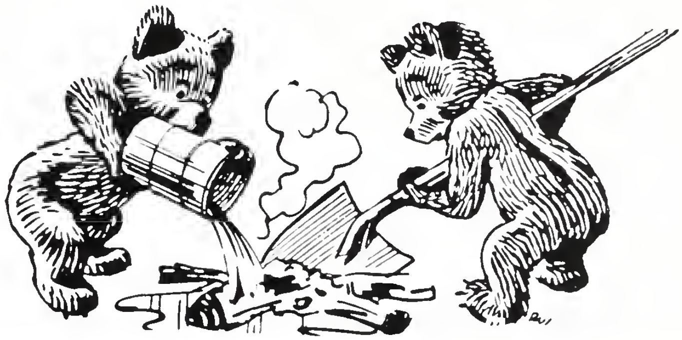
for a final project and creates study plans to accomplish the project in the allocated time.

Module VI: Final Project. After choosing a project, the student carries it out on his or her own unit over a period of several months, writes up the project, and appears before a panel of peers and instructors to present the research and conclusions. To complete the project, the student will use the information and skills gained through the previous modules.

Information

For information about TFM training, contact Reid M. Kenady, Washington Institute Incorporated, P.O. Box 1108, Duvall, WA 98019, telephone (office) 206-788-5161, (FAX) 206-788-0688; or Laurie Perrett, USDA Forest Service, Pacific Northwest Region, Aviation and Fire Management, P.O. Box 3623, Portland, OR 97208. ■

Reid M. Kenady and Laurie Perrett, *respectively, president, Washington Institute Incorporated, Duvall, WA, and cooperative fire specialist, USDA Forest Service, Pacific Northwest Region, Aviation and Fire Management, Portland, OR*



Health Hazards of Smoke

After the serious smoke inversion conditions on the northern California and southern Oregon fires of 1987 and the Greater Yellowstone Area fires of 1988, the National Wildfire Coordinating Group (NWCG) hosted a conference—"The Effect of Forest Fire Smoke on Firefighters"—in San Diego, CA, in 1989. As a result of that conference, NWCG asked the USDA Forest Service's Missoula Technology and Development Center (MTDC) to coordinate the nationwide interagency efforts to identify the hazards of smoke inhalation and then develop and test equipment and procedures to mitigate those hazards.

Under the leadership of the noted exercise-physiologist, Dr. Brian Sharkey, a technical panel has been formed. On it are physicians and industrial hygienists from such diverse groups as Johns Hopkins University Medical Center, the Intermountain Forest Fire Laboratory, the National Park Service, National Institute of Occupational Safety and Health, and the California Department of Health Sciences. Their charter is to review the ongoing research efforts, recommend future research needs, and where feasible, provide funding for needed research through NWGC.

In addition to coordinating the national effort, NWCG has asked MTDC to keep management and the on-the-ground firefighters aware of available information about smoke health hazards. As a result, MTDC has been preparing a semiannual executive report "Health Hazards of Smoke Update." The first report was sent to the field in August 1990 and the second in March 1991. These reports are in user-friendly language; they have already discussed the results of research, detailed the Occupational Safety and Health Administration requirements for respirator use, explained some of the human physiology involved with smoke and particulates, and offered ideas for managers to limit the exposure to inhaling smoke.

For further information of this project or to receive past or future copies of the free "Health Hazards of Smoke Update," contact Dr. Brian Sharkey or fire program leader Dick Mangan at (406) 329-3900 or (FTS) 585-3900; DG:R01A. ■

Dick Mangan, *program leader, USDA Forest Service, Missoula Technology and Development Center, Fire, Aviation, and Safety Program, Missoula, MT*

Improving Airtanker Delivery Performance

Charles W. George and Fred A. Fuchs

USDA Forest Service, team leader, Fire Suppression Technology Unit, Intermountain Fire Sciences Laboratory, Missoula, MT, and assistant director, Fire and Aviation Management, Washington, DC

Since use of airtankers in forest firefighting became an accepted practice late in the 1950's, fire management agencies have provided little specific guidance to operators about how airtanker delivery systems should perform. Agencies have specified airtanker characteristics such as retardant carrying capacity, gross weight, and wheel-loading and speed capabilities. These have generally been dictated by airport runway, taxiway, ramp, retardant base, or other limitations. Other constraints such as the structure of the aircraft fuselage and wing carry-through (spars) also have affected delivery system design. The actual performance of the delivery system has been for the most part a result of the creativity of airtanker owners or operators and their tank designers, responding to the agency's need for an easy-to-use and reliable system within these constraints.

This is not to say agency fire managers did not evaluate delivery system performance. They just did not have the tools or information to provide quantitative data on how much retardant chemical or water is required in given fuel and fire situations—What are the upper and lower limits for effective use of retardant or water? How wide should a retardant line be? What kinds of line increments are most desirable? In addition, the information needed to relate tank design and release characteristics with actual retardant ground distribution patterns was not available. In other words, operators, by trial and error, experience, and assessing what agencies preferred, developed delivery systems to "fill the bill." Numerous delivery systems evolved for a variety of aircraft types. Little standardization resulted, and performance varied. Some systems were fairly versatile, others limited in effectiveness to specific fuel fire situations and sometimes regional conditions.

The Airtanker Board

One of the first attempts to find a way to improve the performance and safety of airtankers began in the 1970's with the Forest Service's formation of the Airtanker Board (ATB) (industry participated as a full member of the ATB). The ATB was formed to assess the worthiness of new aircraft and tank and gating systems that were being proposed to the Forest Service and other fire management agencies for airtanker use. In 1977, with a revised charter and the Department of the Interior, Office of Aircraft Services (OAS), and National Association of State Foresters as new members, the ATB took on an interagency role and became known as the Interagency Airtanker Board (IATB). In this expanded role, the IATB evaluates new or modified airtankers, promotes more effective and efficient airtanker delivery systems, advises agencies, and serves as a central data information source.

Since its beginnings, one of the IATB's primary functions has been to set baseline or minimum requirements for airtankers, focusing on aircraft and delivery system perform-

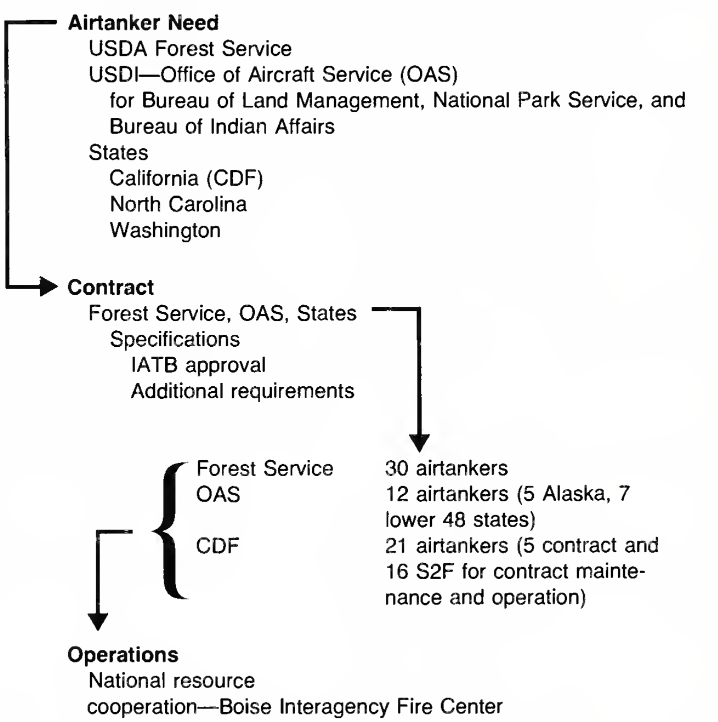


Figure 1—*Interaction of Interagency Airtanker Board approvals and agency needs and specifications.*

ance. These minimum requirements are used to derive a list of "approved airtankers" that are qualified to respond to member agency contracts. Actual contract specifications prepared by user agencies contain a requirement that airtankers must be "approved by the Board" as well as include other specific user requirements. Figure 1 illustrates the interaction of the IATB approvals and agency needs and specifications.

Performance Standards

Initial Evaluation. Initial performance standards were developed around the performance of the existing fleet of aircraft in use by fire management agencies. These standards were written based on a consensus that new aircraft must be "equal or better" in performance than airtankers in the existing fleet. To develop these standards and criteria, the IATB drew upon the knowledge gained from recent research, development, and evaluation programs.

Research Studies—Basis of Evaluation. The evaluation of the performance of the delivery systems derives from research studies initiated by the Forest Service in 1969 to quantify the capabilities of different tank and gating systems. The studies entailed the dropping of retardant or water over a sampling grid and determining the ground pattern under a variety of conditions: tank configuration, door sequencing speed, drop height, retardant type, relative humidity, temperature, windspeed, and direction (George 1975, George and Blakely 1973). Honeywell Corporation, under contract to the Forest

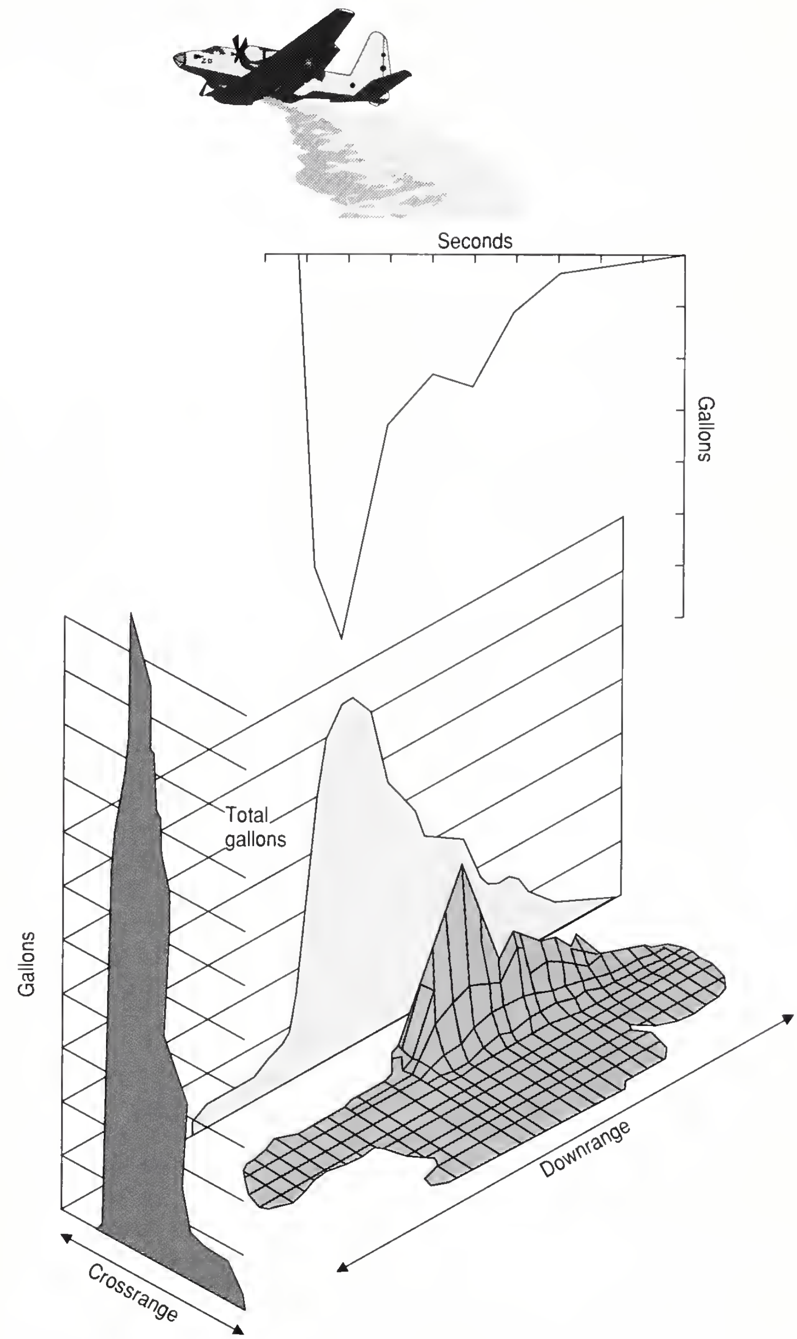


Figure 2—*Relationship between ground distribution patterns and characteristics of retardant flow from the tank system.*

Service, used these data to develop a pattern simulation model whose primary variable was the flow history from the individual systems (Swanson and others 1975). Figure 2 shows the relationship between ground distribution patterns and the characteristics of retardant flow from the tank system. The initial model used flow history derived from motion pictures of airborne airtanker drops. The pattern simulation model (PATSIM) was refined through the use of accurately measured flow data (Swanson and others 1977). PATSIM is illustrated in figure 3. As a better understanding of the mechanisms of retardant breakup, cloud formation, and resulting distribution of retardant on the ground has been gained, additions and modifications to the models have been made and documented (George and Johnson 1990, George 1981). Output from the models has been used in the development of airtanker performance guides and slide chart-retardant coverage computers (George 1981), a tank design guide for fire retardant aircraft (Swanson and Luedecke 1978), guidelines for estimating the effects of downloading (Luedecke and Swanson 1979), and criteria for use in establishing new airtanker requirements.

The first requirements for airtanker delivery systems were developed by examining the performance of airtankers, based on flow rate and volume of drop (tank size) information. This examination identified an important general relationship: Retardant flow rate and volume of drop determine the ground pattern distribution and retardant coverage level. (Coverage levels 1, 2, 3, or 4 refer respectively to 1, 2, 3, or 4

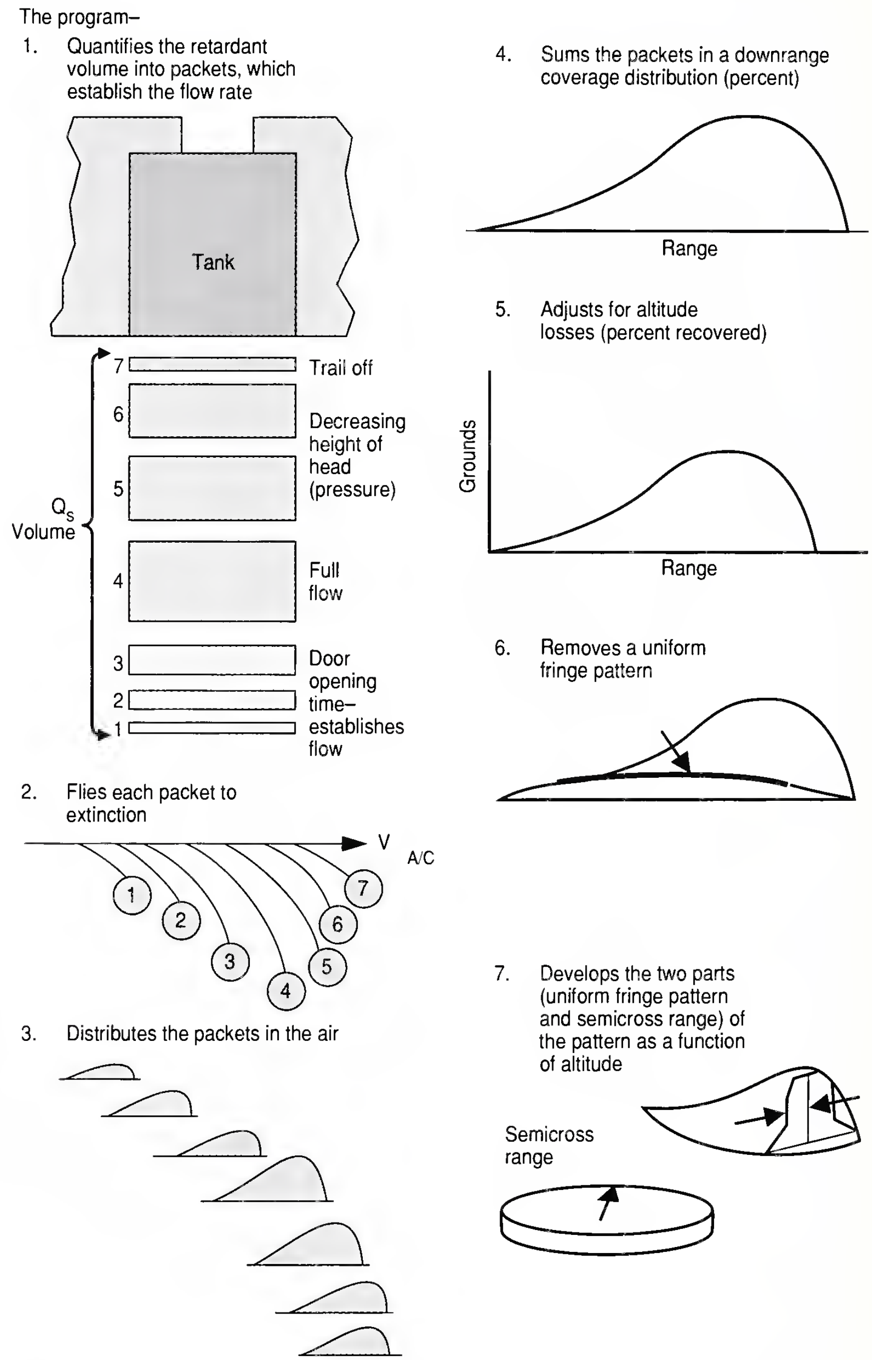


Figure 3—*Pattern simulation model (PATSIM) used to predict ground distribution patterns from retardant release characteristics (Q_s = quantity per unit of time; V A/C = aircraft velocity).*

Research shows that significant improvements in performance of airtanker delivery systems can be obtained by allowing the flow of retardant to be selected and controlled from the tank.

gallons per hundred square feet. Retardant coverage level is expressed as gallons per hundred square feet (gpc) or depth (inches or centimeters).) In addition, specific coverage levels and flow rates have been recommended for the various fuel and fire behavior models (fig. 4). Starting in 1983, field verification of recommended coverage levels was conducted through the multi-year Operational Retardant Effectiveness (ORE) Program.

Regulating the Flow Rate. Knowing this relationship—between flow rate and volume of drop and the distribution pattern and coverage—and the performance of airtankers presently in use, it is obvious that the flexibility and performance of individual airtankers, as well as the entire fleet, could be enhanced by incorporating in each airtanker the ability to regulate the flow rate of retardant during release. With this goal in mind, in 1986, the IATB developed performance criteria that would require a variety of flow rates to be produced by each airtanker. These criteria would thus require modification of existing airtankers to control flow rate in a prescribed manner, depending on the airtanker's retardant capacity, the number of compartments, and the volume of each.

To obtain the desired flow rates, a number of approaches to achieving

Flow rate range	Coverage level	Fuel model NFDRS	Fuel model FB	Description
100–150	1	A,L,S	1	Annual and perennial Western grasses; tundra
		C	2	Conifer with grass
151–250	2	H,R	8	Shortneedle closed conifer, summer hardwood
		E,P,U	9	Longneedle conifer, fall hardwood
		T	2	Sagebrush with grass
251–400	3	N	3	Sawgrass
		F	5	Intermediate brush (green)
		K	11	Light slash
401–600	4	G	10	Shortneedle conifer (heavy dead litter)
		O	4	Southern rough
601–800	6	F,O	6	Intermediate brush (cured), Alaska black spruce
Greater than 800	Greater than 6	B,O	4	California mixed chaparral, high pocosin
		J	12	Medium slash
		I	13	Heavy slash

Figure 4—*Retardant flow-rate range and coverage level recommended for National Fire-Danger Rating System fuel and fire behavior models.*

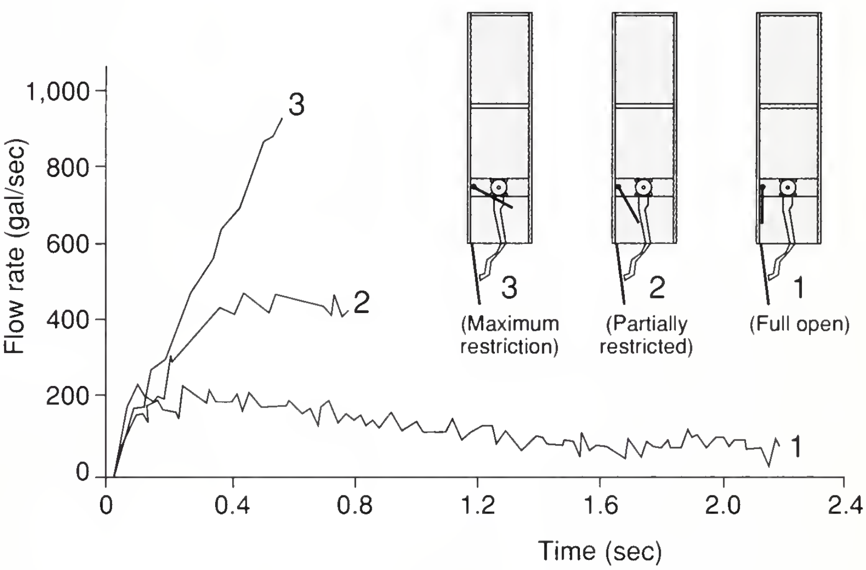


Figure 5—*Diagram of one approach to achieving variable flow rate in a conventional tank.*

control of flow rate are possible. One method of regulating flow is shown in figure 5. To allow for other approaches to achieving the control of flow rate and thus ground coverage levels, evaluation methods were written that would allow actual drop tests to be used to demonstrate that specified ground coverage levels and pattern lengths could be attained with other than conventional retardant delivery systems. Figure 6 depicts an example of a controllable continuous flow system designed to achieve control of flow from a single tank or door system.

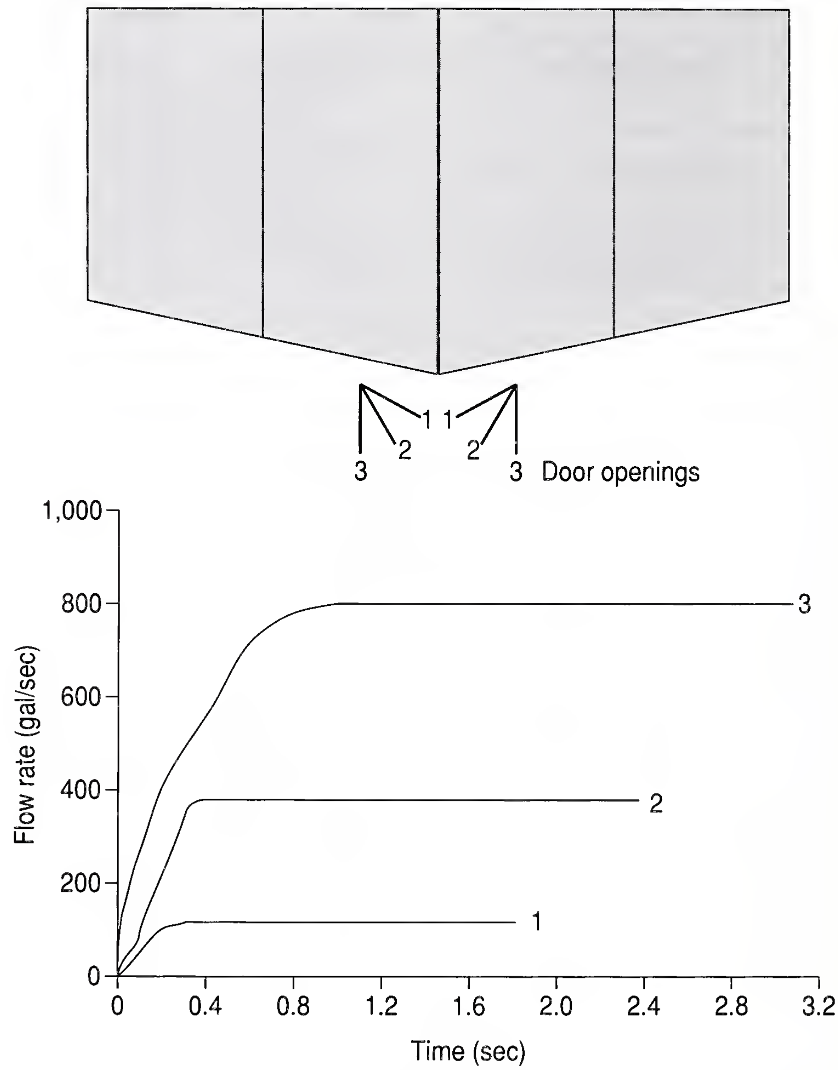


Figure 6—*Diagram of a "controllable continuous flow" SP–2H system.*

Implementing the Board Criteria

To implement the improved IATB delivery system criteria developed in 1986, considerable time and effort has been required. Many of the existing airtankers in the fleet needed to be modified and the designs growing out of the new concepts more than likely added to the design of new aircraft joining the fleet. With this in mind, the IATB set 1990 as the date for implementation, and the improved criteria became known as the "1990 criteria." In late 1989 and early 1990, however, it became apparent that, although private industry was moving to incorporate the new performance requirements, actual implementation in 1990 was overly optimistic. Several systems aimed at meeting the 1990 criteria were developed and placed in service by or before 1990, however, and were fairly successful in demonstrating the flexibility of the new systems (KC–97, C–130, and SP–2H aircraft). These new and improved systems are generally getting good reviews. Better acceptance of the systems can be expected when those involved in their application, including airtanker crews and air attack supervisors are more familiar with them.

These new systems also demonstrated improved efficiency (length of line per gallon of retardant) at the various coverage levels over older unimproved designs. Tables 1 and 2 provide line production values (feet

(0.31 m) of line per 100 gallons (379 L) and total line length per aircraft load) for the old and new improved systems. A summary comparison of line length capabilities of unimproved and improved airtankers at 1,000, 2,000, and 3,000 gallons (3,785, 7,571, and 11,356 L) is given in table 3. The average percent improvement of airtankers meeting the 1990 IATB criteria for coverage levels 0.5 to 4.0 is as follows:

Average improvement of airtankers meeting 1990 criteria

Coverage level (gpc)	*Improvement* (percent)
0.5	57
1	42
2	21

It now appears total implementation of the new performance criteria will occur over the next several years. Design and construction or modification of existing delivery systems is only the first step in attaining the very significantly improved performance and flexibility possible, during actual fire operations. Control systems that contain all the necessary inputs and make flow control or retardant coverage level simple to select might logically be the next essential step in the development. A new approach in selecting the type of drop by air attack supervisors, lead plane pilots, or others instrumental in applying fire retardant must be agreed upon. The emphasis logically should be placed on the "retardant coverage level" for the specific fuel or fire situation. After determination of the appropriate coverage level by the air attack supervisor or other per-

Table 1—*Line production values in feet for unimproved airtankers as a function of coverage level and airtanker volume*[1]

Volume (gallon)	Coverage levels (gpc) 0.5	1	2	3	4	6	8
800	1,288	710	398	273	195	85	0
	(161)	(89)	(50)	(34)	(24)	(10)	(0)
1,000	1,374	793	473	340	254	128	26
	(137)	(79)	(47)	(34)	(25)	(13)	(3)
1,200	1,460	875	547	407	313	172	54
	(122)	(73)	(46)	(34)	(26)	(14)	(5)
1,400	1,547	958	622	473	372	215	82
	(111)	(68)	(44)	(34)	(27)	(15)	(6)
1,600	1,600	1,040	697	540	431	258	109
	(100)	(65)	(44)	(34)	(27)	(16)	(7)
1,800	1,720	1,123	771	607	490	301	137
	(96)	(62)	(43)	(34)	(27)	(17)	(8)
2,000	1,806	1,205	846	674	549	345	164
	(90)	(60)	(42)	(34)	(27)	(17)	(8)
2,200	1,893	1,288	921	741	608	388	192
	(86)	(59)	(42)	(34)	(28)	(18)	(9)
2,400	1,979	1,370	995	808	666	431	219
	(82)	(57)	(41)	(34)	(28)	(18)	(9)
2,600	2,066	1,453	1,070	874	725	475	247
	(79)	(56)	(41)	(34)	(28)	(18)	(10)
2,800	2,152	1,535	1,145	941	784	518	275
	(77)	(55)	(41)	(34)	(28)	(19)	(10)
3,000	2,239	1,618	1,219	1,008	843	561	302
	(75)	(54)	(41)	(34)	(28)	(19)	(10)

[1] Numbers in parentheses are line length/100 gallons.

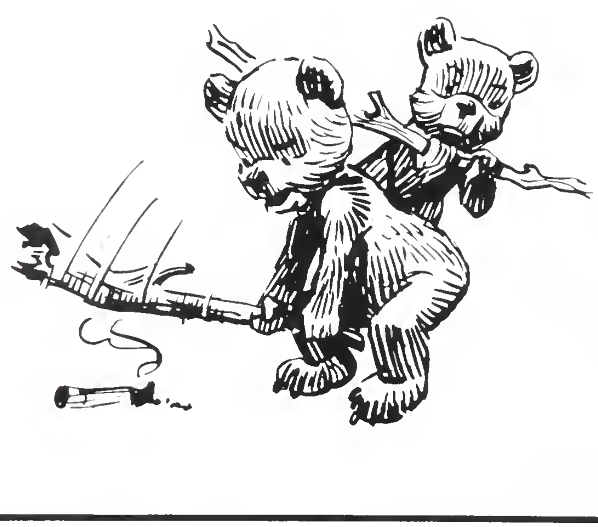


Table 2—*Line production values in feet for improved airtankers as a function of coverage level and airtanker volume*[1]

Volume (gallon)	Coverage level (gpc) 0.5	1	2	3	4	6	8
800	2,246	1,114	526	311	189	38	0
	(281)	(139)	(66)	(39)	(24)	(5)	(0)
1,000	2,337	1,202	607	384	255	90	0
	(234)	(120)	(61)	(38)	(26)	(9)	(0)
1,200	2,429	1,289	687	458	321	142	9
	(202)	(107)	(57)	(38)	(27)	(12)	(1)
1,400	2,520	1,377	768	531	387	194	46
	(180)	(98)	(55)	(38)	(28)	(14)	(3)
1,600	2,611	1,465	848	604	454	245	84
	(163)	(92)	(53)	(38)	(28)	(15)	(5)
1,800	2,702	1,552	929	678	520	297	121
	(150)	(86)	(52)	(38)	(29)	(17)	(7)
2,000	2,794	1,640	1,009	751	586	349	158
	(140)	(82)	(50)	(38)	(29)	(17)	(8)
2,200	2,885	1,728	1,090	824	652	400	196
	(131)	(79)	(50)	(37)	(30)	(18)	(9)
2,400	2,976	1,815	1,170	897	718	452	233
	(124)	(76)	(49)	(37)	(30)	(19)	(10)
2,600	3,068	1,903	1,251	971	784	504	270
	(118)	(73)	(48)	(37)	(30)	(19)	(10)
2,800	3,159	1,991	1,331	1,044	850	556	308
	(113)	(71)	(48)	(37)	(30)	(20)	(11)
3,000	3,250	2,078	1,411	1,117	916	607	345
	(108)	(69)	(47)	(37)	(31)	(20)	(12)

[1]Numbers in parentheses are line length/100 gallons.

Table 3—*Comparison of line-length capabilities of improved and unimproved airtankers*

Volume	Line length (feet) for coverage level (gpc)[1] 0.5			1			2			3			4		
(gallon)	U	I	PI	U	I	PI	U	I	PI	U	I	PI	U	I	PI
1,000	1,374	2,337	70	793	1,202	52	473	607	28	340	384	13	254	255	0
2,000	1,806	2,794	55	1,205	1,640	36	846	1,009	19	674	751	11	547	586	7
3,000	2,239	3,250	45	1,618	2,078	28	1,219	1,411	16	1,008	1,117	11	843	916	9

[1]U = unimproved tank; I = improved tank meeting 1990 criteria; PI = percent improvement

sonnel, the airtanker pilot or crew then simply selects that level requested from his system control or display.

Applying existing knowledge and technology available to the problem of aerial retardant delivery and fire suppression and using the methods and process briefly described here, or some similar approach, should provide these results:

- Improved performance
- Increased flexibility
- Increased efficiency
- More consistent results
- Greater overall fire suppression capability ■

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Field Use of Improved Airtankers and Retardant Tanks

More Reliable and More Efficient

Tank and gating systems on aircraft have evolved during the last 20 years into very reliable and increasingly efficient dispensers of fire retardants and suppressants. These developments have resulted from cooperation between government and private industry, both making a significant contribution to improved retardant tank performance.

Cooperation and an Important Product

The Operational Retardant Effectiveness (ORE) Program, a multi-year retardant coverage evaluation program lead by the USDA Forest Service Intermountain Fire Sciences Laboratory at Missoula, MT, helped identify areas in the tank and gating system needing improved performance. Using ORE team data, the airtanker industry produced several technical improvements to their tank and gating systems. One important improvement growing out of recent cooperation is the solid-state digitized intervalometer. This new generation "electronic box" gives the airtanker pilot a much more accurate way to open a series of tank compartments on the airtanker. What does that mean to firefighters?—a more uniform and controllable retardant coverage level on the ground. Sincc most retardant is used to build a chemical fireline around the fire, uniformity and continuity of the retardant on the ground is very important.

Recent Improvements ...

... to the Tank. The most recent improvements in retardant tank system efficiency are being made to the tanks themselves. In the past, the flow rates from various types of tank systems varied greatly. Using the technical advice of the Missoula laboratory, air tanker operators are modifying the flow-rate characteristics of their retardant tanks so that all systems will be able to produce similar flow rates.

... to the Terminology. One of the major benefits of the latest improvements is a simplified and standardized retardant prescription terminology. Previously, fire suppression managers needed to use a large database of retardant prescription terminology to compensate for the variances among tank systems. Since all modified tanks will now be able to produce similar flow rates, drop instructions to flight crews can now be given in terms of "coverage level" instead of "door numbers" and "time delays." A fire manager can now simply ask for whatever coverage level fits the situation of a ground fire. No longer does he or she have to figure out how many doors at a specific time delay to request from the airtanker. The flight crews of each air tanker will be able to set the proper door sequence and time delay, or in some cases, dial in the requested coverage level into an onboard computer.

There are many advantages to such a system. There is less room for error. The simplicity of the system shortens training time for firefighters and eliminates cumbersome books and slide-rule type computers. The valuable data contained in the old formats has now been absorbed into the new tank systems.

Another advantage will be to shorten the amount of radio communication that was necessary with the old retardant coverage prescription terminology. Shorter radio messages are more easily understood and leave more time available to the flight crews and ground crews for other important communications and tasks in the high workload environment over a wildfire.

What's Ahead

What is emerging from these efforts to improve retardant tank system performance is an example of technology benefitting operational field personnel directly engaged in wildfire suppression. The challenge is now for national and regional level fire and aviation managers to train, use, evaluate, and continue improving this valuable fire suppression tool. ■

Dave Nelson, *regional aviation officer, USDA Forest Service, Region 3, Albuquerque, NM*

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A Tribute to Smokejumpers: Dedication of the National Wildland Firefighters Memorial

"In the first place, the best information I can get from experienced fliers is that all parachute jumpers are more or less crazy—just a little bit unbalanced, otherwise they wouldn't be engaged in such a hazardous undertaking . . ." wrote Regional Forester Evan W. Kelley in a letter to Mr. Earl W. Loveridge in 1935. Fifty-six years later, the smokejumper program is now one of the most efficient means of initial attack on remote wildfires. The smokejumper program began in 1939, and the first fire jump was made by Earl Cooley and Rufus Robinson on the Nez Perce National Forest in 1940.

National Wildland Firefighters Memorial. Each stone bearing the name of a smokejumper is marked by a rose.

Smokejumper Training Rigors

Smokejumper candidates must go through a month of rigorous training before being qualified to jump to a wildfire. Candidates must already be experienced firefighters before coming to the smokejumper program. Smokejumper training includes a week long "rookie camp" where grueling line digging is practiced and timed, and 110-pound (50 kg) packouts must be accomplished. In the 2-week practice units that follow, smokejumpers learn jump procedures and safety practices, perform simulated jumps and gradually work up to eight practice jumps. The final week is spent on practice jumps and classroom training in first aid, helicopter training, fire behavior, and safety procedures.

Now the real challenge lies ahead of the rookies—an actual fire jump. Each jumper exits the airplane wear-

Bob Sallee, last survivor of the Mann Gulch Fire in which 13 smokejumpers lost their lives in 1949.

ing an extra 65 pounds (30 kg) of protective equipment. Jump suits are made of tough Kevlar fabric and lined with foam padding. Once on the ground, the jumper removes the suit and fights fire in the lighter-weight Nomex® shirts and pants. When the hard work of putting out the fire is completed, the jumper then must lug an 85- to 110-pound (39- to 50-kg) gear bag, sometimes as far as 15 miles (24 km) to the nearest road.

The Mann Gulch Fire

Smokejumping reached a low point in August of 1949 when 13 smokejumpers perished in the Mann Gulch Fire on the Helena National Forest. Only 3 of the 16 men on the fire survived when the fire suddenly exploded, trapping the jumpers in the steep gulch. Wagner Dodge, the smokejumper foreman, lit an escape fire and walked in behind the flames. Foreman Dodge attempted to gather his men into the burn, but due to the roar of the flames, smoke, and confusion, the men misunderstood the plan and chose to try and outrun the fire. Only two jumpers made it to the ridgetop and down into what is now known as Rescue Gulch. It was there that Walter Rumsey and Robert Sallee sought refuge from the Mann Gulch flames. Foreman Dodge survived the flames by remaining inside his own backfire. As a result of this tragedy, new techniques in fire suppression, along with an intense study of fire behavior and fire safety became of utmost importance. With the investigation of the Mann Gulch Fire came new knowledge and understanding of fire behavior. This understanding is passed on to all fire crews through classroom and on-the-job training on fires.

In smokejumping's 51-year history, the Mann Gulch jumpers have been the only smokejumpers to die in the line of duty while fighting a wildfire. In over 350,000 jumps, only 3 jumpers have died in jump-related accidents. The smokejumpers' record speaks for itself. These men and women are among the best trained firefighters in the world. But you won't hear any of them tell you that.

Recognition and Appreciation

Formal recognition of those young men who died fighting the Mann Gulch Fire has been conspicuous by its long absence. However, on May 8, 1991, the National Wildland Firefighters Memorial was dedicated at the Aerial Fire Depot in Missoula, MT. Families and friends of the Mann Gulch smokejumpers attended the dedication, coming from all over the country. The formal ceremony helped to finally heal the emotional wounds left by the tragic Mann Gulch Fire, as heard from many who attended. A letter from Johan Newcombe, sister of one of the men who died at Mann Gulch, stated: "I want to say thank you to each and all for your perseverance in gathering everyone for the Memorial Dedication. It was truly a fantastic experience. Meeting friends of Raymond's, seeing the Base, University of Montana, and so on, has really helped to fill the void in my life—that I've felt for 42 years. Now, I understand so much. Everyone there, families and friends, came away enriched by the experience." ■

Tracey Nimlos and Timothy Eldridge, *respectively, purchasing agent and assistant manager of the Smokejumper Visitors Center, USDA Forest Service, Region 1, Aerial Fire Depot, Missoula, MT*

The Heavy-Lift Helicopter and Fire Retardant Drops at the Stormy Fire Complex

Lynn R. Biddison

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The use of the heavy-lift helicopter[1] to carry fire retardant to wildland fire control is relatively new. The heavy-lift helicopter, classified as a Type I helicopter in the National Wildfire Coordinating Group's Fireline Handbook 3, was first extensively used to drop fire retardant on the 1986 Garden Valley fires on the Boise National Forest. Columbia Helicopters using a Vertol 107 with a 1,000 gallon (3,785 L) bucket, successfully dropped fire retardant on those fires. During the 1987, 1988, and 1989 fire seasons, the heavy-lift helicopter saw considerable use and gained the support and confidence of Incident Commanders, operation chiefs, air operation directors, and others. At the August 1990 Stormy Fire Complex on the Sequoia National Forest in California, the largest number of heavy-lift helicopters for use at a wildland fire was assembled.

Lightning Strikes

On Sunday, August 5, 1990, a dry lightning storm struck much of southern and central California. On the Sequoia National Forest, this storm started over a dozen fires. All but two of them, the Black and Stormy, were controlled by initial attack forces. These two fires in heavy brush below extensive timber stands in nearly inaccessible areas of the Kern River drainage escaped from strong aggressive initial attack efforts. When controlled, the fires had blackened some 24,200 acres (9,800 ha) of watershed, prime timber lands, and wildlife habitat.

Order for a Mobile Retardant Base and Fire Retardant

On Monday, August 6, a Class I Interagency Fire Team arrived to direct the suppression efforts for the two fires. By this time, the Black and Stormy Fires were threatening to become one large conflagration. These fires later became known as the Stormy Fire Complex.

At 2:30 p.m. on August 6, Operations Chief Lonnie Briggs (Los Padres National Forest) and Air Operations Director Bob Reece (Yosemite National Park) ordered a portable fire retardant base for use with the Type I heavy-lift helicopters they planned to order.

Chemonics, FIRE-TROL®, at Orland, CA, received the order for a mobile retardant base (MRB) at 3:30 p.m.[2] The MRB arrived at Kernville at 9:30 a.m. on August 7. Shortly after, a tank truck and trailer with a supply of FIRE-TROL® LCA, a liquid concentrate and long-term fire retardant arrived. By 2:00 p.m., the unit was ready to deliver 450 gallons (1,703 L) of mixed fire retardant per minute.

Mobile Retardant Base Equipment. The FIRE-TROL® MRB, a totally self-contained unit, consists of the following:

- A trailer-mounted pump and orifice blender for proportioning liquid FIRE-TROL® LCA concentrate and water into mixed fire retardant and loading the mixture into helicopter buckets, dip tanks, or airtankers
- Water pumps
- Water storage tanks
- Tank trailer or flex-tanks for FIRE-TROL® LCA concentrate
- Couplings, manifold, loading valves, and accessories
- Retardant dip tanks

A suitable water supply is required at or near the retardant base location.

Helicopters. On August 6, there were several small- and medium-sized helicopters on the fire, assigned to moving firefighters to the fireline and keeping them supplied. The fire team ordered a number of medium- (Type II) and heavy-lift (Type I) helicopters. The helicopters in use at the peak of the helicopter mobilization were the following:

Type I	*Type II*
2 Chinook B–234	3 Bell 205 (Hueys)
2 S–61	1 UH–1 (Huey)
1 S–64	2 206 B–3
1 Chinook CH–47	2 206 L–3
	1 Kaman
	1 Bell 204 (Super Huey)
	1 S–58

The Helibase—Its Managers and Services. The helibase for the complex was established at the Kern Valley Airport under the direction of helibase manager Jim Boukadis of the Sequoia National Forest. As part of the operation, Manager Boukadis

[1]The Incident Command System classifies helicopters in four categories or types. Type I lift helicopters must be capable of hauling 16 passengers (including pilot), have a gross weight of over 12,500 pounds (5,670 kg), and be capable of carrying 700 (2,650 L) plus gallons of fire retardant. For example, a Bell 214 is a heavy-lift helicopter.

[2]The use of trade names does not constitute official endorsement of the product by the USDA Forest Service.

established the retardant base, under the supervision of Dan Kellogg from the Coronado National Forest, at a large parking area on the airport. A separate base for servicing and parking the Type I heavy-lift ships was established about 2 miles (3 km) south of the airport. This base was under the supervision of Mike Fogarty from the San Bernardino National Forest. The air attack supervisors also worked out of the Kern Valley Airport and Helibase. Crash and rescue service was provided by personnel from the China Lake Naval Weapons Center. Because the Stormy Fire Complex was not far from the Kern Valley Airport and generated a lot of air traffic, the Bakersfield, CA, office of the Federal Aviation Administration, upon request of the U.S. Forest Service, sent two flight controllers to the airport.

The Type I heavy-lift helicopters were so successful that the Incident Commander was able to release the airtankers from the Stormy Fire Complex for assignment to other fires.

Retardant Delivery Start-up. On August 8, Rogers Helicopters and Siller Bros., call-when-needed helicopters (CWN), started operations from the retardant base, using a Kaman and an S–61. They delivered 12,800 gallons (48,452 L) of FIRE-TROL® LCA fire retardant to the fireline.

Next-Day Delivery and Evacuation. On August 9, 77,100 gallons (291,847 L) of LCA fire retardant were delivered to the fireline by the following helicopters:

- Kaman (1 helicopter, 2 trips, Rogers Helicopters) 1,600 gallons (6,053 L)
- S–61 (1 helicopter, 25 trips, Siller Bros.) 15,000 gallons (56,780 L)
- S–64 (1 helicopter, 5 trips, Siller Bros.) 5,000 gallons (18,927 L)
- B–234 (1 helicopter, 19 trips, Columbia Helicopters) 55,550 gallons (210,274 L)

Columbia Helicopters's B–234 dipped LCA from a 5,000-gallon (18,927-L) dip tank it brings with its helicopters. The other ships dipped from the dip tanks provided with the MRB.

At approximately 3:00 p.m., the California Department of Forestry helicopter 101 (UH–1) informed Stormy Air Attack, erratic fire behavior made it necessary to evacuate fireline personnel from Helispot 2. Radio transmissions from 101 and Air Attack indicated additional aircraft were needed to expedite the evacuation. To help with the emergency, Morgan Mills, Region 5 helicopter specialist and pilot, authorized the use of restricted category helicopters to supplement other helicopters at the scene. Two B–234's, a Kaman, and a S–58 were reassigned to assist with the evacuation. Over 200 people were flown to safety in approximately 40 minutes.

Three Days of Retardant Deliveries. On August 10, helicopter retardant operations began at 8:00 a.m. and had to be terminated at 4:10 p.m. because of heavy smoke and poor visibility. During this 8-hour period, 189,500 gallons (679,414 L) of fire retardant were delivered to the fireline. The ships involved and the gallons delivered were:

A Chinook B–234 with a 3,000-gallon (11,356-L) bucket (right) and a S–64 with a 2,000-gallon (7,571 L) bucket (left) filling up with fire retardant at the Mobile Retardant Base at the Stormy Fire Complex.

- B–234 (2 helicopters, 61 trips, Columbia Helicopters) 176,300 gallons (667,348 L)
- S–61 (1 helicopter, 20 trips, Siller Bros.) 12,000 gallons (45,424 L)
- Kaman (1 helicopter, 3 trips, Rogers Helicopters) 1,200 gallons (4,542 L)

The round-trip times for the B–234's, devoted solely to dropping LCA long-term fire retardant, were most often in the 9- to 13-minute range. The S–61 and Kaman were used intermittently to drop fire retardant. At other times, they dipped water from a stream, added a Class A foam concentrate in flight, and delivered this mixture to the fireline.

On August 11, helicopter retardant operations began at 8:43 a.m. and terminated at 6:15 p.m. During this period of time, 193,640 gallons (694,258 L) of fire retardant were delivered from the base to the fireline. The ships involved and the gallons delivered were:

- B–234 (2 helicopters, 57 trips, Columbia Helicopters) 164,300 gallons (621,925 L)
- S–61 (1 helicopter, 27 trips, Siller Bros.) 16,200 gallons (61,312 L)
- S–64 (1 helicopter, 7 trips, Siller Bros.) 7,140 gallons (27,027 L)
- Kaman (1 helicopter, 15 trips, Rogers Helicopters) 6,000 gallons (22,712 L)

The B–234's dipped the mixed retardant from one dip tank. The Kaman dipped from a separate tank. The S–61 and S–64 buckets, each equipped with a Kam-lock fitting, were filled by a 3-inch (7.6-cm) hose directly from the MRB trailer-mounted blending and loading pump. This same unit was also keeping the dip tanks filled with retardant.

The B–234's were assigned primarily to deliver fire retardant. The other ships were periodically assigned to deliver fire retardant and at other times to dip water from a stream, add a Class A foam concentrate inflight, and deliver this to the fireline.

The round-trip times for the B–234's were most often in the 10- to 16-minute range; the Kaman, 16- to 23-minute; and the S–61, 10- to 17-minute. S–64 use was too intermittent to permit calculating meaningful round-trip times.

FIRE-TROL® LCA was blended at the ratio of 5 parts water to 1 part LCA. The water was pumped directly from the Kern River to portable tanks that are part of the MRB. It was possible to mix and load 193,640 gallons (732,986 L) of fire retardant in only 10 hours from one fire retardant base.

On August 12, helicopter retardant operations began at 7:24 a.m. with two Columbia Helicopters, B–234's. By 11:30 a.m., they made 21 round-trips delivering 61,400 gallons (232,417 L) of fire retardant to the fireline. At 11:14 a.m., the S–61 and S–64 were again assigned to retardant operations. Total retardant delivered for the day was 133,625 gallons (505,811 L).

The breakdown by ships and gallons delivered is as follows:

- B–234 (2 helicopters, 33 trips, Columbia Helicopters) 97,100 gallons (367,753 L)
- S–61 (1 helicopter, 23 trips, Siller Bros.) 12,525 gallons (23,846 L)
- S–64 (1 helicopter, 16 trips, Siller Bros.) 24,000 gallons (90,847 L)

The round-trip times for the B–234's were from 13 to 36 minutes; for the S–61 from 10 to 27 minutes; and the S–64 from 9 to 28 minutes.

On August 12 at approximately 5:30 p.m., the Nick Fire started in the Domeland Wilderness Area of the Sequoia National Forest. Air tankers and handcrews were not available. Three of the Type I heavy-lift helicopters with retardant were diverted to this fire. The fire was controlled at 42 acres (17 ha). Incident Commander Mike Smith reported this would have become another major fire without the heavy-lift helicopters and the fire retardant they were able to deliver from the MRB.

During the Stormy Fire Complex, many major fires burned throughout central and northern California, Idaho, Oregon, Washington, and Alaska. As a result, there was a critical shortage of airtankers. The Type 1 heavy-lift helicopters were so successful that the Incident Commander was able to release the airtankers from the Stormy Fire Complex for assignment to other fires. In addition, because of topography on parts of the incident, only helicopters could safely and successfully drop fire retardant.

The Stormy Fire Complex demonstrated that Type I heavy-lift helicopters operating from an MRB can deliver fire retardant to the fireline effectively and with a positive cost-benefit ratio. Cost figures for the 1990 fire season, developed by Jerry Vice, helitack specialist, Forest Service, Pacific Southwest Region, show the average delivery cost of fire retardant from the Type I helicopters to be 0.65 cents per gallon. Delivery costs of retardant from airtankers are

in the range of $1.00 to $1.25 per gallon.

The use of Type I heavy-lift helicopters on large fires is not a replacement for any currently used resources. They are another tool extremely useful in the proper time and place to wildland firefighters. ■

Rebuilding FEPP Engines: A Nebraska Innovation Improves Quality

The problem described by the fire chief from the Friend Rural Fire District, a fire district in a community with a population just over 1,000 in southeastern Nebraska, was not a new one. The district's Federal Excess Personal Property (FEPP) water tanker (a 1952 military General Motors Corporation (GMC) 6 × 6) was not running well. It did not have much oil pressure, was making unusual engine noises, and was suddenly short of power. The solutions offered by the local mechanic in Friend were: Try to repair the vehicle or replace it entirely. But, he went on to say he would not attempt the engine repair because he "knew nothing about those old trucks."

After pricing an all-wheel drive replacement vehicle, the fire chief called the Nebraska Forest Service, the source from whom the fire district acquired the vehicle some years earlier, and asked if help was available. The answer was—"Yes!"

The Nebraska Forest Service Fire Equipment Shop in Lincoln, NE, has provided FEPP vehicles to Nebraska's fire districts since 1963. During this time, many military-type FEPP vehicles in various stages of disrepair passed through the shop, emerging mechanically sound and ready for assignment to fire districts. The "tired engine" problem was originally solved by removing a good running engine from a vehicle that had other mechanical troubles. However, as the engines aged, the quality of the "take-out" engines declined.

Engine Rebuilding

In the early 1980's, an engine-rebuilding program was begun with the goal of having, on hand, one rebuilt motor for each type of military FEPP vehicle used in the Nebraska Forest Service fire protection program. As a result, engines were rebuilt and either shipped to the rural fire district for installation or installed at the fire equipment shop.

The engines installed at the shop were driven 50 to 100 miles (81 to 161 km) after installation. This "break-in" time allowed mechanics to adjust the carburetor and also to find leaks or other problems. Engines shipped directly to the field and installed there often did not perform as well as shop-installed engines.

Stand for Engine Testing

As a result of all this, our engine-rebuilding mechanic, Don Vietz, suggested that an engine "test stand" be built for each type of engine. Each rebuilt engine would be operated at varying speeds for 4 to 6 hours—tested to identify problems—before installation or shipping.

A test stand for the GMC 6 × 6 engine, the most frequently overhauled, was built first, and later one was built for the REO 6×6. A welded angle-iron frame with motor mounts, radiator, control panel, compressed air tank, electric fuel pump, and an exhaust pipe with muffler was built using many components from a "cannibalized" 6×6 engine.

When an engine overhaul has been completed, the unit is then placed on the test stand and all of the sending units for the control panel gauges are hooked up so that oil pressure, water temperature, air pressure, and charging rate can be monitored while the engine is on the test stand. At this time, the carburetor is adjusted, ignition timing set, the engine checked for leaks, and any other problems that might surface are fixed immediately.

The end result is a rebuilt motor that runs well and is ready to install in a FEPP firefighting vehicle with minimum downtime and maximum user confidence. ■

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